

# NASA CONTRACTOR REPORT

PROFILE User's Guide

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# PROFILE User's Guide

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### 1.0 GENERAL INFORMATION

#### 1.1 Summary

This report provides user information for program PROFILE, an aerodynamics design utility for refining, plotting, and tabulating airfoil profiles. The theory and implementation details for two of the more complex options are also presented. These are the REFINE option, for smoothing curvature in selected regions while retaining or seeking some specified thickness ratio, and the OPTIMIZE option, which seeks a specified curvature distribution. REFINE uses linear techniques to manipulate ordinates via the central difference approximation to second derivatives, while OPTIMIZE works directly with curvature using nonlinear least squares methods.

Use of programs QPLOT and BPLOT is also described, since all of the plots provided by PROFILE (airfoil coordinates, curvature distributions) are achieved via the general-purpose QPLOT utility. BPLOT illustrates (again, via QPLOT) the shape functions used by two of PROFILE's options. These three utilities should be distributed as one package. All are implemented in FORTRAN 77. They were developed on a VAX-11/780 under VMS for the Applied Aerodynamics Branch at NASA Ames Research Center, Moffett Field, California, by staff from the Palo Alto office of Informatics General Corporation, under Contract NAS2-11555-307-1.

The plots produced by QPLOT require the widely-available DISSPLA\* graphics package, which may inhibit some potential users, but PROFILE and BPLOT are readily portable. Translation of the plotting part of QPLOT to some other graphics package should be straightforward for those without access to DISSPLA. Plots are crucial to the effectiveness of PROFILE and BPLOT.

#### 1.2 Introduction

Program PROFILE is a utility for computational aerodynamic applications. Originally intended for plotting airfoil coordinates and tabulating derivatives, it has evolved into a more powerful package capable of modifying airfoils in a number of ways. It has thus become a useful design tool. Profiles may be perturbed through interactive application of shape functions, refined by seeking desired second derivative distributions while

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\* DISSPLA is a proprietary product of ISSCO, San Diego, and is not available from NASA. It may be purchased under license.

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adjusting thickness ratio, or optimized by seeking target curvature distributions directly.

Most of the options apply to a single two-dimensional airfoil section per run, although handling of multiple sections in the same input data file is provided for in two cases: sections of a wing (new plot page for each section); and the elements of a multi-element airfoil such as a wing with a slat (all elements appear on the same plot frame). The more sophisticated options offer "before" and "after" plots of both the airfoil and its curvature distributions (upper and lower surfaces on separate frames).

The simpler options include redistributing the data points in a variety of ways, and renormalizing the coordinates. Three standardized geometry data formats are provided for compatibility with most computational flow codes.

PROFILE provides a cheap and easily-used means of illustrating and refining airfoil geometry data. It should serve as a flexible vehicle for additional capabilities, which airfoil designers are encouraged to incorporate as their needs arise.

### 1.3 Environment

PROFILE is an interactive program developed on a Digital Equipment Corporation VAX-11/780 under VMS V3.6. It is written in FORTRAN 77, with VAX extensions used in certain places where adhering to the strict standard was either out of the question (such as the READONLY keyword on explicit OPEN statements for reading files not owned by the user), or considered too restrictive (as in the case of the long variable names in certain routines). All computations are performed in single precision (32-bit words on the VAX).

Plotted results are essential to effective use of PROFILE. However, plotting is invariably installation-specific. This is one reason that PROFILE itself does not perform any graphics - it is more portable that way. The other reason is that some of the plottable data output from one run of PROFILE (specifically, the curvature data) may be reused as input for another run. Instead, advantage has been taken of a general-purpose plot package known as QPLOT, developed under the same contract as PROFILE. QPLOT uses DISSPLA (referenced above), and should accompany any distribution of PROFILE.

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The "device-independent" intermediate files produced by QPLOT (for previewing on a video display terminal, or post-processing on a hard-copy device such as a Versatec plotter) are in a format peculiar to the NASA Ames environment, although a simple change in the device initialization can produce other types of intermediate files. See Appendix B for more on QPLOT.

A second supplementary program that should accompany distributed copies of PROFILE is known as BPLOT, described in Appendix A. BPLOT produces plots - again, via QPLOT - of the "bump" functions employed by PROFILE in its MODIFY and OPTIMIZE modes.

### 1.4 Future Directions

An enhanced PROFILE, contemplated at the time of writing, would provide for truly interactive graphics as opposed to end-of-run graphics. For instance, in the MODIFY mode, perturbations could be tried, viewed, and perhaps undone and retried, in a single session instead of requiring several runs of PROFILE as at present. The graphics could be fairly crude (given the resolution of today's video display terminals), would probably provide windowing (i.e., enlarging, for the same reason), and could be achieved with a much less bulky graphics package than DISSPLA.

Generation of Cp distributions is another possibility appropriate to PROFILE given that this can be done cheaply with good approximations, at least for subsonic flows. Boundary layer displacement thickness distributions could be generated similarly.

Treating curvature as a single distribution rather than separate distributions for upper and lower surface may be more effective for some purposes. The authors and sponsors of PROFILE encourage users to adapt this tool to suit their needs, in the belief that a sound framework has been provided in the present code for capabilities unforeseen so far. Feedback is welcomed, and conscientious adherence to the standards of modern software engineering is urged upon those designers inclined to perpetuate the programming style (or lack thereof) for which engineers have long been notorious.

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### 2.0 BASIC INPUT DESCRIPTION

PROFILE has numerous modes of operation, some of which require considerable activity at the keyboard during program execution. Details of such interactive entries are described in the appropriate subsections of Chapter 4. The basic inputs common to all modes are described here.

An airfoil dataset and control inputs are required for every run of PROFILE, in two separate files. PROFILE prompts for these file names.

#### 2.1 Airfoil Data Format

The airfoil dataset may be input in one of three formats, and also may be output in any of the three formats described below. The first format shown is the most common and is known as "STANDARD" or "PROFILE" format.

LEGEND		< CHARACTER*80 >
NU UPPER SURFACE		< I4, 1X, UPPER SURFACE >
X	Y	< 2F10.0 >
X	Y	< 2F10.0 >
.	.	.
.	.	(May be X/C, Y/C;
.	.	Xs are increasing.)
NL LOWER SURFACE		< I4, 1X, LOWER SURFACE >
X	Y	< 2F10.0 >
X	Y	< 2F10.0 >
.	.	.
.	.	(Xs are increasing.)
.	.	.
.	.	.

The other two formats are wrap-around clockwise and wrap-around counterclockwise, where the coordinates begin at the trailing edge, wrap around the leading edge, and end at the trailing edge. The clockwise case begins with the lower surface, and the counterclockwise case begins with the upper surface. The format shown below is essentially the same for both cases. NPTS is the total number of points in the dataset.



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LEGEND		< CHARACTER*80 >	
NPTS		< I4 >	
X	Y	< 2F10.0 >	
X	Y	< 2F10.0 >	
.	.	.	(May be X/C, Y/C;
.	.	.	Xs are decreasing
.	.	.	until the leading
.	.	.	edge, then increasing)

### NOTES:

- \* With PROFILE format the lower surface coordinates are optional, but a zero must be read for NL if no lower surface is included.
- \* If both surfaces are present (PROFILE format), they must have the same leading edge point. The trailing edge points may differ.
- \* The descriptive first line is termed a "legend" because it appears as a legend, not a title, on the airfoil plot that is obtainable with PROFILE.
- \* There may be more than one set of coordinates in the same file (all formats).
- \* Multi-element airfoils may be in any of the three formats, with a set of coordinates for each element. Unless each element is to be represented separately in the legend, one legend entry should be included with the first set of coordinates and a blank line should precede any following sets.
- \* The 2F10.0 is not strictly necessary, as PROFILE uses list-directed reads rather than formatted reads. This is partly because the subroutine PRREAD is used for reading more than just airfoil coordinates. But 2F10.0 is a popular standard.

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### 2.2 Control Inputs

Control inputs common to all modes are represented by keywords and values in the input control file. PROFILE prompts for the name of this control file. A description follows, with the default value for each keyword in parentheses. Note that synonyms are permitted in a couple of cases. Note also that several keyword/value pairs may appear on one line, except for the multi-valued keywords LINE and NOFILE, which must not appear with other keywords.

KEYWORD	VALUES	DESCRIPTION
FORMAT	(SAME) PROFILE or STANDARD CLOCKWISE COUNTERCLOCKWISE	One of three formats for output profile(s). May be in standard PROFILE format, clockwise wraparound format or counterclockwise wrap-around. SAME means the same format as the input profile.
LEADING_EDGE	(BLUNT) SHARP	Type of leading edge. Parametric splines are used for airfoils with blunt leading edges and ordinary natural splines are used for airfoils with sharp leading edges.
LINE	(SOLID) (DASH) DOT CHAINDASH CHAINDOT THICK SYMBOLS	Controls line types of curves on profile plots. One value may be included for each curve on the plot. The default is a solid line for the first curve, a dashed line for the second curve, then lines with symbols for any following curves. The first curve would typically represent the original profile, with the second curve representing the revised profile. Overriding the default might be necessary when plotting multi-element airfoils, or when overlaying more than 2 airfoils. At most 20 curves are provided

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		for.      Note: The keyword SYMBOLS refers to symbols without a line connecting them.
MAXCURVATURE	(+5.)	Cutoff values for plotting curvatures. Practice shows that +/-5. give useful plot scaling by ignoring the high curvature values near the leading edge. On the other hand, the user may well want to focus on the leading edge region.
MINCURVATURE	(-5.)	
NOFILE	(NONE) DAT PLT TAB CRV YPP	Used to suppress any combination of the five output files generated by PROFILE. The values correspond to the file name extensions - see BASIC OUTPUT DESCRIPTION.
PLOT	(BOTH) ORIGINAL REVISED	Controls plotting of original and revised profiles. The default is to plot both original and revised (if one exists).
THREED	(FALSE) or (NO) TRUE or YES	For plotting of multiple stations from a 3D wing. The default is the 2D case, giving all airfoil curves on the same plot frame. When THREED is true, each airfoil found in the input dataset is plotted on a separate frame.
XAXIS	(6.4)	Length of x-axis in inches. The default is appropriate for an 8.5 x 11 page.
XMIN	(minima and maxima of the input coordinates)	Minimum abscissa of window
XMAX		Maximum abscissa of window
YMIN		Minimum ordinate of window
YMAX		Maximum ordinate of window

Any or all of the last four keywords may be used to plot a portion (window) of the profile plot.

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A sample input control file follows. Note that keywords and values may be separated by blanks, commas, colons, equal signs or tabs. As mentioned above, keywords with more than one value should appear on a separate line. Keywords (and text-type values) may be truncated to any set of unambiguous leading characters.

```
LEADING_EDGE: SHARP   FORMAT=STANDARD   PLOT REVISED   THREED: NO
MINCURVATURE = -6.   MAXCURV   6.
XAXIS = 16.3   XMIN = .2   XMAX: .8   YMIN -.03   YMAX = .04
LINE = SOLID, SOLID, DOT, DOT
NOFILE: DAT YPP
```

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### 3.0 BASIC OUTPUT DESCRIPTION

PROFILE produces up to five different output files. The NOFILE keyword in the input control file (previous section) can be used to suppress any unwanted files. All the output files are named with a common identifier chosen by the user, each with a different extension. The five standard extensions are listed below, using the default identifier PROFILE.

PROFILE.DAT	Revised airfoil data file (requested format).
PROFILE.PLT	Plottable airfoil data file (QPLOT format).
PROFILE.TAB	Tabulations and diagnostics, for printing.
PROFILE.CRV	Curvature data file (QPLOT format).
PROFILE.YPP	2nd derivatives file (PROFILE format).

Each output file is described in more detail in the sections that follow.

#### 3.1 Revised Airfoil Coordinates

The <identifier>.DAT file contains the airfoil coordinates that have been revised in some way. The file can be in any of the three formats described in the BASIC INPUT DESCRIPTION and can be used in subsequent runs of PROFILE.

#### 3.2 Plottable Airfoil Data

The <identifier>.PLT file contains airfoil coordinates in the plottable form handled by QPLOT (Appendix B). Normally, one plot frame is produced (but see THREED usage below). A plot of one single-element airfoil may contain up to two curves, one representing the original input coordinates, and another overlaid curve to represent the revised coordinates. The keyword PLOT in the input control file specifies which of the curves are plotted (i.e., original, revised, or both). For modes 1 through 3, only the revised profile is plotted, since there should be no visual difference between the original and revised profiles in these cases.

The plot may contain more than 2 curves (up to 20) in the case of a multi-element airfoil, or when several airfoils are to be superimposed for comparison. If multiple sections of a wing are indicated via the THREED keyword, these are plotted separately on multiple frames.

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A prompt is issued for a title which will be centered at the top of the plot. This title will also appear as the legend entry in the revised airfoil dataset (if one is requested), and is used to identify any revised data in the <identifier>.TAB and <identifier>.CRV files. An optional subtitle will also be centered under the title.

A variety of line types may be specified in the input control file. (See BASIC INPUT DESCRIPTION for details on line types, particularly for the multi-element case.) A legend centered above the axes identifies the curve(s).

### 3.3 Tabulations

The <identifier>.TAB file contains tabulations of the profile coordinates as well as the values of 1st and 2nd derivatives and curvature at each point. When the profile has not been revised, tabulations for only the original profile are printed, otherwise tabulations for both the original and revised profile are included. Details of the iterative computations are also printed here if REFINE or OPTIMIZE mode is being used. Other diagnostics written to the .TAB file include the number of profiles identified during the preliminary scan of the .DAT file (for overall data range purposes), and a record of the shape functions selected if the MODIFY option is used.

### 3.4 Curvature Data

The <identifier>.CRV file contains abscissas and curvature values in the form expected by QPLOT. Upper and lower surface curvatures will be plotted on separate frames, with up to three curves on a frame. Original curvatures are included for mode 0, original and revised curvatures for modes 1 through 5, or original, revised and target curvatures for mode 6. (For details on target curvature distributions, see the OPTIMIZE mode in Chapter 4.) By default, the curvature values plotted will range between -5. and +5., but these limits can be redefined using the input keywords MINCURVATURE and MAXCURVATURE. (All values are written to the .CRV file; it is QPLOT that suppresses those outside the chosen range during plotting.) The curvature data can also be edited and reused as input when running PROFILE in the OPTIMIZE mode.

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### 3.5 Second Derivatives

The <identifier>.YPP file is a table of 2nd derivatives at each point on the airfoil in standard PROFILE format. When the profile has not been revised (MODE=0), derivatives for the original profile will be in the file, otherwise only derivatives for the revised profile are included. This avoids mistakes when the file is reused (probably after editing) as an input file for PROFILE's REFINES option. In this mode, the  $Y''$  values are used to act as constraints on the curvature. See section 4.6 for more on the reuse of 2nd derivative values.

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### 4.0 MODES OF OPERATION

Although there are several modes of operation available in PROFILE, all of them require the same basic inputs (i.e., an airfoil dataset and a control input file), and nearly all of the output options are available for each mode. The principal difference between modes is in the method(s) used to manipulate the airfoil geometry, which are detailed in this chapter.

PROFILE can be run in only one mode at a time, selected from a menu. It may be necessary to run the program several times for one airfoil, depending on the options desired. These options are described in roughly the order of complexity.

#### 4.1 MODE=0: Tabulate and/or Plot (No Modifications)

This mode does nothing to modify the input coordinates (with the possible exception of writing the coordinates to disk in a format different from the input format). Select MODE=0 simply to plot an airfoil and/or its curvature distributions, or to generate the 2nd derivatives needed for reuse (after editing) in a REFINED mode run.

#### 4.2 MODE=1: Rectify Leading Edge Definition

This mode is used to "rectify" the leading edge definition in cases where the current leading edge is not the most forward point on the airfoil. For example, some NACA airfoils have negative abscissas on the upper surface and leading edge defined as (0.,0.). This causes the upper surface to be multi-valued, creating problems with spline fitting and the addition of shape functions. MODE=1 finds the minimum abscissa on the airfoil and uses this as the leading edge point common to both surfaces, shifting the upper and lower surface points accordingly. The result is an airfoil with a "true" leading edge and monotonically increasing abscissas.

#### 4.3 MODE=2: Normalize/Denormalize

This mode renormalizes airfoil coordinates. PROFILE determines the chord of the (first) input airfoil and prompts the user for whether to normalize the coordinates by this chord (resulting in an airfoil with a chord of 1.) or by some other value. If some other positive value is entered, a prompt will be issued for the coordinates of the leading edge point as well. If the chord value entered is negative, the (presumably



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normalized) profile will be denormalized by the absolute value of that chord.

Care must be taken when more than one airfoil is processed at a time, as with a 3D case or a multi-element airfoil. The same renormalization is applied to all airfoils in the input dataset.

### 4.4 MODE=3: Redistribute Airfoil Coordinates

This mode redistributes the airfoil abscissas in one of several ways, according to the option chosen from another menu. Either parametric or ordinary natural splines are used to derive the ordinates, depending on the value of keyword input LEADING\_EDGE. The menu selections are shown below.

MENU SELECTION	DESCRIPTION
-1	Here, the new abscissas are to be read from a file prepared by the user in standard PROFILE format. Ordinates may or may not be included, although they will be ignored. A line of text (even if blank) should be included at the beginning of the file in place of the legend entry. A prompt will be issued for the name of this file.
0,1,2	These menu selections use the subroutine XGRID to redistribute abscissas within the range of the original coordinates. Prompts are issued for the desired number of abscissas to be redistributed on the upper and lower surfaces. Descriptions of each of these options follow.
0	Uniform spacing.
1	Sinusoidal bunching near the leading edge.
2	Sinusoidal bunching near both the leading and trailing edges.
3	This menu selection is reserved for some other method of redistribution in a user-supplied version of XGRID (in which case the program would require relinking).

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### 4.5 MODE-4: Modify Airfoil Using Perturbing Functions

This mode allows the user to perturb each of the airfoil surfaces by applying shape functions interactively, according to the menu below.

SCALE	1: $Y = Y * P1$
TRAILING	2: $Y = X ** P1$
DROOP	3: $Y = e ** ( -P1 * X )$
LEADING	4: $Y = ( 1. - X ) ** P1$
EXPONENTIAL	5: $Y = X ** P1 * ( 1. - X ) * e ** ( -P2 * X )$
SINE	6: $Y = SIN ** P2 ( PI * X ** ( LOG(.5)/LOG(P1)) )$
WAGNER	7: Wagner function; P1 = Order of requested term

Where appropriate, prompts are issued for the parameters P1 and P2 and for a multiplier of each function selected. Each surface is perturbed independently with as many shape functions as desired. There is an option to start over in case of error, before moving on to the next surface. The selected shape functions, parameters, and multipliers are echoed in the <identifier>.TAB file, which may be printed for future reference. See Appendix C for illustrations of the shape functions available.

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### 4.6 MODE=5: Refine Airfoil by Manipulating Y"

#### 4.6.1 Motivation and Analysis:

The REFIN option that is now part of PROFILE arose from a requirement to adjust the thickness ratio of an airfoil that had been produced by the design-by-optimization program FLO6QNM [4]. Simple scaling of all of the ordinates is known to cause loss of some of the properties that have been laboriously achieved through the optimization process. The curvature in the leading edge region, and perhaps the trailing edge region, plays a significant role in the flow characteristics, so a technique was sought which would retain the original curvature distribution as much as possible while producing a desired thickness.

Curvature, K, is defined in terms of first and second derivatives, Y' and Y'', as follows:

$$K = \frac{Y''}{(1 + Y'^2)^{3/2}} \quad (4.6.1)$$

The motivation for the method implemented as REFIN is that, if Y' is small, then curvature K is very like second derivative Y''. Now Y'' can be represented as a finite difference expression which is a linear combination of ordinates Y:

$$Y''_i = \frac{2 \left( DX_i Y_{i-1} - (DX_i + DX_{i-1}) Y_i + DX_{i-1} Y_{i+1} \right)}{DX_i DX_{i-1} (DX_i + DX_{i-1})} \quad (4.6.2)$$

$$\text{where } DX_i = X_{i+1} - X_i$$

Reading Eq. 4.6.2 the other way around suggests a set of simultaneous equations in the UNKNOWN ordinates Y(i) with DESIRED values of the 2nd derivative (and hence, approximately, the curvature) on the right hand sides. Furthermore, airfoil thickness can be modified by some sort of scaling of the original ordinates. This suggests an additional set of equations. Thus an overdetermined system of linear equations for the ordinates can be set up, the optimal solution of which tends to satisfy the combined requirements involving thickness and curvature.

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The basic idea of posing the problem as a linear least squares one proves to be more powerful than was initially envisioned, as will be explained below. But first, a look at the system that is set up and solved for N points defining one surface:

$$Z(i) = \text{scale}(i) * Y(i) \quad (i=2:N-1) \quad (4.6.3)$$

$$Z''(i) = Y''(i) \quad (i=2:N-1) \quad (4.6.4)$$

where  $Z$  represents the revised form of ordinates  $Y$ ;

and  $\text{scale}$  is the (normally nonlinear) distribution of scale factors which yields the specified thickness ratio in an iteration to be described below.

Note that end points  $i=1$  and  $i=N$  are omitted because the central difference formula does not apply there. This is not a problem, since the values for  $Z(1)$  and  $Z(N)$  must equal  $\text{scale}(1)*Y(1)$  and  $\text{scale}(N)*Y(N)$  - not just approximately - in order that the two surfaces retain their common leading edge (and possibly trailing edge) point.

The system shown as Eq. 4.6.5 is of order  $2(N-2)$  by  $N-2$ , and is very sparse since the upper half is strictly diagonal and the lower half is tridiagonal. The two terms "B" in the right hand side represent the desired values of  $Y''$  for  $i=2$  and  $i=N-1$ , adjusted in the usual way by the appropriate multiples of the known values for  $Y$  at  $i=1$  and  $i=N$ .  $SY$  represents  $\text{scale}(i)*Y(i)$ .

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$$\begin{array}{l}
 i=2 \quad \text{-->} \\
 \\
 \\
 \\
 i=N-2 \quad \text{-->} \\
 i=2 \quad \text{-->} \\
 \\
 \\
 \\
 i=N-2 \quad \text{-->}
 \end{array}
 \begin{bmatrix}
 x & & & & & & & & \\
 & x & & & & & & & \\
 & & x & & & & & & \\
 & & & . & & & & & \\
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 & & & & & x & & & \\
 & & & & & & x & & \\
 x & x & & & & & & & \\
 x & x & x & & & & & & \\
 & x & x & x & & & & & \\
 & & . & . & . & & & & \\
 & & & . & . & . & & & \\
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 & & & & & x & x & x & \\
 & & & & & & x & x &
 \end{bmatrix}
 \begin{bmatrix}
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 \end{bmatrix}
 =
 \begin{bmatrix}
 SY \\
 SY \\
 SY \\
 . \\
 . \\
 . \\
 SY \\
 SY \\
 B \\
 Y'' \\
 Y'' \\
 . \\
 . \\
 . \\
 Y'' \\
 B
 \end{bmatrix}
 \quad (4.6.5)$$

### 4.6.2 Weighting the Y" Equations:

Since values of Y" tend to be considerably larger than values of Y (particularly near the leading and trailing edges), the two halves of Eq. 4.6.5 require equilibrating in some sense. This is achieved by applying multiplicative weights less than unity to the lower half, so that Eq. 4.6.4 becomes

$$\text{weight}(i) * Z''(i) = \text{weight}(i) * Y''(i) \quad (i=2:N-1) \quad (4.6.6)$$

Furthermore, nonuniform weighting of the Y" values is advisable, just as nonuniform scaling of the Y values is necessary, but for different reasons. In Eq. 4.6.3, scale(i) must vary from a value of 1.0 at leading and trailing edges to that factor at the point of maximum thickness which gives the desired thickness. In the case of the second derivative weights, smooth variation over an order of magnitude has been found to give best results: typically 0.004 at leading and trailing edges up to 0.04 at some interior point (yet to be specified). (This sort of nonlinearity reflects to some extent the fact that Y" is much smaller in magnitude in the mid-section than it is fore and aft - more than an order of magnitude, typically. The goal is to retain the curvature as much as possible towards the extremes, so the outer equations of Eq. 4.6.6 still tend to dominate in terms of residual over the inner equations.) The weighting prevents the residuals of Eq. 4.6.3 from being swamped by those of Eq. 4.6.4.

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### 4.6.3 Smoothing the Y" Right-Hand-Side Values:

Selection of the point with maximum weight cannot be described until an unanticipated benefit of this computation is explained. The reader may be surprised if he plots a few typical curvature distributions: they can be remarkably spiky and far from smooth. It makes little sense to strive to retain these spiky distributions. Smoothing out the Y" values used on the right-hand-side of Eq. 4.6.6 is highly desirable. And here is where the aptness of the term REFINE may be appreciated: we have a means of tailoring the Y" distribution (and hence the curvature) to any reasonable, smooth, shape we choose. Since smoothness and general shape are more fundamental than absolute values here, it does not matter that all equations in the overdetermined system cannot be solved exactly. Moreover (and this answers any objection that Y' is NOT negligible in the fore and aft regions of most interest), it does not matter that we are working with Y" rather than curvature K. For if the right-hand-side values used in Eq. 4.6.6 are related to, or varied systematically from, the original Y" values, and the revised values Z for ordinates Y bear some relationship to the original Y values (as they do by construction), then the first derivatives of the Z values, and hence the revised curvature values, cannot help but bear some relationship to the original values - smoothed out in the qualitative way that is now seen to be desirable.

### 4.6.4 Nonlinear Weights and Scales:

Returning to the question of where to choose the peak weight for the Y" values, the answer is that point where some spike or unwanted bump in the original curvature distribution showed up. We have a means of zeroing in on the offending features of the distribution (not necessarily all in the same run, though!).

Thus the kind of nonlinearity sought (for both the weights and the scales) involves known values at the end points and a known value at a known interior point - the center of some glitch in a region of the curvature in the case of the weights, or the abscissa where the airfoil thickness is greatest in the case of the scale factors. A function with the necessary properties is given by

$$P3 * ( \text{SIN} ( \text{PI} * X ** P1 ) ) ** P2 \quad (4.6.7)$$

where  $P1 = \text{LOG}(0.5) / \text{LOG}(X\text{-at-peak})$ , which serves to locate

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- the peak of the sine in the desired place;
- P2 = a "width" parameter, where 2.0, 3.0, or 3.5, say, give more and more "peaky" distributions, while 1.0, 0.5, ... give broader distributions; and
- P3 = a multiplier to alter the sine's peak value, which is 1.0 for any P1 and P2.

The scale factors of Eq. 4.6.3 require further explanation. If the equation for the point where maximum thickness occurs were solved exactly, it can be shown that the desired thickness would be obtained by using

$$P3 = 1.0 - \langle \text{desired thickness} \rangle / \langle \text{original thickness} \rangle$$

and also using  $1.0 - P3 * \sin \dots$  rather than  $P3 * \sin \dots$ . Note that this scaling is applied to either surface or to both, since  $S*(YU - YL) = S*YU - S*YL$  in the case of both surfaces.

However, none of the equations of the overdetermined system is solved exactly. This means an iteration is necessary, whereby the  $\langle \text{desired thickness} \rangle$  above is treated as a target which is adjusted away from the true desired thickness until a match is obtained to within some suitably small tolerance. The algorithm for adjusting the "target" involves two "calibration" computations, after which linear interpolation between the two most recent estimates suffices till convergence. An oscillation may be observed between two abscissas showing maximum thickness if the thickness calculation is confined to the original, discrete, abscissas. This tends to slow the convergence, but should not be a problem. (More continuous computation of thickness using a spline on one surface must be used if the two surfaces are not defined at the same abscissas. However, the present implementation switches to the more correct calculation only if it detects different sets of abscissas.)

### 4.6.5 Setting Up the Target Y" Values:

Preparation of the target Y" values also requires explanation. This has been made as convenient as possible. If the curvature distributions are already smooth and about as good as the user knows how to ask for, then REFINER can compute and use these with no other inputs.

Alternatively, some single region at a time may be targeted for smoothing simply by responding to prompts for a constant value of Y" over some X-range. This works well for spikes, or

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broader bumps, in the mid-section curvature, and can also be handy for constraining curvature away from zero, where the airfoil may be excessively flat or reflexed. It can also work in noisy regions near the leading or trailing edges, since constant  $Y''$  (which tends to lead to smooth  $Y$  and hence  $Y'$ ) can still lead to smoothly varying curvature as required. To repeat an earlier statement: it does not matter that we are constraining  $Y''$  rather than curvature.

More generally, REFINER has the option of reading a table of  $Y''$  values so that more than one unsatisfactory region can be refined in a single run. This table is prepared in exactly the same format as for the airfoil itself, and may start out as the table saved by an earlier run of PROFILE. The table does not have to be complete: linear interpolation is done for abscissas in the table range (meaning chunks can be edited out where linear variation of  $Y''$  is considered acceptable), while the original  $Y''$  values are used for abscissas outside the table range. This kind of tailoring of the second derivative targets may take practice to get a feel for what is achievable and what is not. It is certainly flexible, but the user should keep in mind the simpler mechanism for "zapping" isolated spikes or bumps in the curvature described previously.

### 4.6.6 Solution of the Overdetermined System:

While the system set up and solved can be thought of as two groups of constraints - one on ordinates, one on second derivatives, it is treated here as an ordinary overdetermined system of equations with no constraints in the linear programming sense. In the original implementation, no attempt was made to take advantage of the sparsity of Eq. 4.6.5. The simplicity of a good direct method for dense systems, using the QR factorization [6] as in subroutine HDESOL, was preferred to existing alternatives for sparse systems that were likely to be iterative.

However, this meant a lot of storage for the  $2M \times M$  matrix ( $M=N-2$ ), and a lot of computation for typical values of  $M$  - a computation that is usually iterated 3-5 times till the desired thickness is achieved. (The storage requirement was about  $300 \times 150 = 45000$  words for up to 150 points per surface to be handled, while the CPU time per iteration of the refinement calculation (both surfaces refined) was measured at about 16 seconds on a VAX-11/780 for the typical value of 72 points per surface.)



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A specialized scheme has therefore been implemented for this diagonal-plus-tridiagonal structure. Subroutine DTDLSQ still forms the QR factorization, but much more efficiently than the general-purpose HDESOL. (The coding for use of HDESOL has been left in the source for REFINE, commented out, as an aid to understanding the set-up of the overdetermined system.) The above storage requirement has been reduced to  $4 * 150 = 600$  words, while the CPU time per refinement iteration has become about 0.8 seconds on the VAX (both surfaces, 72 points per surface).

Note that working with the QR factorization [6] of this matrix  $A$  is certainly preferable to setting up and solving the too-often-seen Normal Equations (involving  $A$ -transpose  $* A$ ). Not only would the latter method require double the precision (word-length) to give an accuracy comparable to that of the single-precision computation used here.

### 4.6.7 Some Further Notes on Usage:

The available before-and-after plots of curvature, plus the tabulations, should help the user to decide how to vary some of the interactively-entered inputs. It may take several tries to achieve acceptable results. Sometimes one should use REFINE on the results of the last REFINE application; in other cases, it may be better to throw away a result and back up for a retry.

Another point to remember is that the default range for the curvature plots is intended for a good presentation of the mid-section by suppressing the handful of large values that appear near the leading edge and possibly trailing edge. The user may not want to ignore these larger values - plotting them by expanding the range defined by MINCURVATURE and MAXCURVATURE is advisable, along with observing them in the tabulation.

Note that finite differencing is used for estimating  $Y'$  and  $Y''$ , and hence curvature, rather than the analytic derivatives that splines can provide. The experience of the authors is that interpolating splines tend to produce surprisingly wavy distributions for the higher derivatives, even for "good" airfoils. The sign of  $Y''$  can be very sensitive to small changes. Finite differences, on the other hand, exhibit steadier behavior. More importantly, since the essence of the method is to use a central difference expression for  $Y''$  to define the lower half of the left-hand-side matrix of Eq. 4.6.5, consistency demands that the right-hand-side terms also be derived using central differences. Thus PROFILE eschews splines throughout for tabulation purposes, and for computations, though

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it does use them for redistributing data points.

If the airfoil is defined on too fine a mesh, using the traditional 2F10.6 format, zeros can easily show up for the Y" estimates near the leading edge where they are clearly not reasonable. This is due to catastrophic cancellation in the presence of too few significant digits. Going to, say, E15.6, helps superficially, but makes little sense because airfoils cannot be constructed to one part in a million. The moral? Avoid excessively fine airfoil meshes: 192 points in the range [0.,1.] is too many.

### 4.6.8 Summary of Interactive Inputs Used in REFINE Mode:

Short descriptions of the quantities for which REFINE prompts the user are given below. All have defaults where possible, as indicated by <CR> (Carriage Return). The user is urged to experiment with various combinations till some sort of feel for cause and effect is attained. Only then can the power of REFINE be exploited effectively.

- \* Desired % thickness: <CR> retains present thickness.
- \* Width param. for Y: Affects the nonuniform scaling applied to the ordinates (both surfaces. The default is 2.0. Larger (3.0-4.0) tends to retain leading/trailing edge shape more while 1.0 would constrain fore and aft less.
- \* Input Y" table: <CR> means there is none, else the file name is entered. This file should be in the same "PROFILE" format as the airfoil coordinates. It can cover any range of abscissas. (Linear interpolation is used.) It may be an edited version of the file from a previous run of PROFILE, or it may be much cruder.

WARNING: If you delete points as you smooth out this distribution, it is easy to forget to update the integer number of points at the beginning of the data for each surface. Incorrect counts here can lead to obscure errors.

- \* Constant Y" value: <CR> means no such constraint; retain existing curvature values as much as possible. Otherwise, a value of Y" entered will be sought in the abscissa range

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that is prompted for next.

- \* Corresp. X range: Enter low and high X values on the same line. Allow for the fact that strict inequalities are used when the program tests for being within this range. E.g.: Enter .39 .61 or .39, .61 if you intend the constraint to apply over [0.4,0.6].
- \* Width param. for Y": Default is 3.0. Affects non-uniform weighting of the equations representing 2nd derivative constraints in the overdetermined system being solved. Since the actual values of the 2nd derivatives being sought also act in a weighting sense, effects of this variable are not easy to predict. Values of 2.0 or 1.0 should tend to let Y" change more.
- \* X for peak Y" weight: Default is 0.5. The absolute values of Y" are so much bigger than those of Y that they all need to be scaled down in the system being solved. If you are trying to flatten the curvature plot in some region, then pick the center of the region for this input. Otherwise, use the mid-chord value.
- \* Y" weights, X/C=0,1: Default is 0.004. See next.
- \* peak Y" weight: Default is 0.04. These provide for the fact that the absolute values of Y" are typically smaller in the mid-section than near the leading/trailing edges, so they should be weighted more, especially in view of the fact that any Y" constraints applied are typically in the mid-section. See above.

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### 4.7 MODE=6: Optimize Airfoil by Manipulating Curvature

#### 4.7.1 Motivation and Analysis:

The OPTIMIZE option incorporated in PROFILE is a natural generalization of the ideas embodied in the REFINE option. This mode of perturbing an airfoil works directly with the curvature distribution rather than the second derivatives. The price paid is that linear techniques can no longer be employed. Nonlinear optimization is typically much more expensive in terms of CPU time. On the other hand, OPTIMIZE mode offers a design method that is much cheaper than working with pressure distributions, which involve at least one flow field solution for each evaluation of the objective function being minimized. The hope is that at least some of the work it takes to optimize airfoils can be done on a modest scale by tailoring the curvature distribution first.

The implementation is analogous to that of optimizing flow codes such as FLO6QNM\*: set up some target distribution and seek to match it as well as possible in the least squares sense by applying appropriate shape functions or "bumps". As is true with flow optimization, constraints of some kind are almost essential. Here, it is most likely to be the maximum thickness that has to be constrained somehow. Given that the minimization algorithm used, QNMDIF\*, is an unconstrained one, we have two choices: use a penalty function to keep thickness within reasonable limits (and then perhaps use REFINE mode on the result to give the preferred thickness precisely); or hope for the best by solving without constraints and, again, relying on REFINE to adjust the result. If the target curvatures are at all reasonable, the second approach may well be adequate.

Note that there is no "multiple design point" complication (referring to the desirability of optimizing airflow characteristics at more than one flight condition at the same time). In fact, no attempt is made to manipulate more than one surface at a time; the upper and lower surfaces can be optimized independently in separate runs of PROFILE, with little loss of generality and significant simplification.

Prospective users of the OPTIMIZE option should be aware that it will probably take a lot of tries with different shape

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\* FLO6QNM [4] links a 2D potential flow code, FLO6, with a reliable optimization package known as QNMDIF [1] plus a scheme for estimation of optimal finite differencing intervals. FLO6QNM was developed under the same contract as PROFILE.

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functions, initial airfoils, target curvature distributions, and scale factors, before an acceptable result is achieved from a sufficiently well-posed, well-scaled optimization problem. The initial airfoil is included here as a variable, because if it is not smooth to start with, perturbing it with smooth shape functions cannot be expected to produce smooth curvature distributions close to the (presumably smooth) target distribution. Use of the REFINE option first may be desirable, which raises the question of staying with the reliability and greater simplicity of REFINE in favor of OPTIMIZE's uncertain behavior. (The optimizing package may not converge to a minimum of the objective function, though it will almost certainly reduce its value below the initial value. But a lowered objective function does not necessarily represent an acceptably smooth solution, as in the case of oscillations observed occasionally when just Wagner functions are applied.)

To this, the response must be that one does not know until one tries both possibilities. The OPTIMIZE option is presented as a potentially powerful tool, exercised by the authors on only a limited number of applications at the time of writing. Feedback from adventurous users is welcomed.

An outline of the OPTIMIZE method used in PROFILE follows:

- \* Select upper or lower surface, and save the original coordinates for repeated application of varying shape functions.
- \* Display present thickness ratio; prompt for desired one. Defaulting means either to retain the same thickness, or that the user doesn't care; in the latter case, the prompt for the penalty parameter to be used to impose a thickness constraint should be defaulted (to zero, meaning no such constraint).
- \* Set up the user-defined "bumps", either by parsing a file of keywords and values prepared ahead of time (more on this below), or by choosing the first N Wagner functions, which are easily definable without such a file.
- \* Read the target curvature distribution, which is most likely an edited form of an output file from an earlier run of PROFILE.
- \* Extract the active variables from the given set - not all of the parameters involved will be free to change - some may be specified as inactive or fixed.

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- \* Compute the initial value of the objective function, and estimate optimal finite differencing intervals.
- \* Minimize the objective function (quasi-Newton method, without analytic derivatives).
- \* Repeat the best function evaluation, and update the airfoil surface permanently.
- \* Display the thickness actually achieved; perform the rest of PROFILE's plotting and tabulations.

### 4.7.2 Preparing the Target Curvature Distribution:

One of PROFILE's options is to generate a plottable file of curvature data. Typically, the plot for one of the surfaces, or both, will exhibit imperfections that the designer would like to eliminate. PROFILE offers two choices: the REFINER option, which uses second derivative distributions rather than curvature and is described elsewhere; and the OPTIMIZE option which works directly with curvature. The designer edits the imperfect values to smooth them out in some way, assisted by the original plot, then reruns PROFILE in OPTIMIZE mode, hoping that the new plots of curvature (showing revised and original distributions superimposed) will show a good match.

Remember that OPTIMIZE mode can work with only one surface at a time. The input file of target curvatures is assumed to contain only the relevant surface. It is also assumed to retain the title and two axis labels that the original QPLOT file contained. The title is transmitted to the output tabulation, along with the target curvature values; the labels are ignored. (More precisely: the target file may contain both surfaces, but only the first surface is read, so it must be the appropriate one.)

There is a question as to how many of the chordwise values should be retained in the target curvature distribution. There are considerations such as the fact that the values near the leading edge, being larger in magnitude, may tend to dominate the sum-of-squares objective function. (Extreme leading and trailing edge values, however, are suppressed by PROFILE in the plottable files and tabulations.) In the absence of a scheme for weighting the elements of the sum of squares (which could be implemented in much the same way as it has been in the REFINER option), it is probably best to retain target values for all interior abscissas, if only to avoid surprises in any region

omitted.

## 4.7.3 Selecting the Shape Functions:

Appropriate selection of the shape functions is probably the most difficult aspect of using PROFILE's OPTIMIZE option. There is no single choice for any given situation. Experience is desirable to help pick a subset that should do the job. In general, all of the bumps selected should be distinctly different in some sense - it is unwise to include two functions that have similar effects, as this adds unnecessary variables and blurs the minimum from the optimizing algorithm's point of view. If the changes being sought in the curvature are localized in some way, then some of the functions can be localized or centered similarly.

PROFILE offers two basic sets of perturbing functions: six "bump" functions [3], and a family known as the Wagner functions [5]. All of these are illustrated in Appendix C. The perturbing functions to be used may be specified in two ways: in a previously-prepared file containing keywords and values; and a simpler way that is convenient if only the Wagner functions are to be used. (See below for more on the use of the Wagner functions.)

Specification of the bump functions to be used has been made as mnemonic and straightforward as possible. There is no need for hard-coding the set of bumps - a keyword-driven input scheme is used, involving preparation of a small file that will look something like the following sample:

```
BUMP: SINE
CENTER: 0.5   STATUS: INACTIVE
WIDTH:  3.0   STATUS: INACTIVE
MULTIPLIER: 0. STATUS: ACTIVE  SCALE: 100.
```

```
BUMP = exp
POWER = 15.   STATUS = fixed
WIDTH = 10.   STATUS = fixed  SCALE = 1.
MULT = .001   STATUS = variable SCALE: 10.
```

```
:
```

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### Points to note:

- \* Format is free, with several possible delimiters; blank lines are optional, but good for separating bumps.
- \* Keywords need only be long enough to be unambiguous.
- \* Either upper or lower case is permitted.
- \* Keywords for a given bump must begin with the BUMP keyword, which must be the only keyword on the line.
- \* The ordering of subsequent lines describing that bump's variables or parameters is unimportant, but if some are omitted, they will be detected as undefined, and execution will halt. There is NO ATTEMPT TO DEFAULT values.
- \* Variable names for a given bump (e.g. WIDTH) must be the FIRST keyword on a line, one per line.
- \* STATUS and SCALE may be in either order within a line.
- \* SCALE is optional if STATUS is FIXED/INACTIVE/CONSTANT.
- \* SCALE is defaulted if STATUS is ACTIVE/FREE/VARIABLE and no entry is given. (1.0 is the default.)
- \* End-of-file signals end of data. Some special keyword would probably be necessary on a mainframe.

The terminology requires further explanation. First, all of the perturbing functions (including the Wagner functions) have MULTIPLIERS which are almost certain to be included among the optimizing variables. Second, all of the functions are additive - multiples of the basic shapes are added to the original airfoil. Third, each bump type has a descriptive name, and is a function of a normalized abscissa  $x$  and of parameters with descriptive names, as shown below. (The SCALE function is an exception to all of these statements - it simply scales the ordinates  $y$  directly.)



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Bump Name	Parametric Expression
DROOP	$\exp(-\text{WIDTH} \cdot x)$
EXPONENTIAL	$x^{\text{POWER}} * (1-x) * \exp(-\text{WIDTH} \cdot x)$
LEADING	$(1-x)^{\text{POWER}}$
TRAILING	$x^{\text{POWER}}$
SINE	$(\sin(\pi * x^{(\log(0.5)/\log(\text{CENTER}))}))^{\text{WIDTH}}$
SCALE	$y * \text{FACTOR}$
WAGNER	$\begin{aligned} & (t + \sin(t))/\pi - \sin(0.5t) \quad (N = 1) \\ & (\sin(Nt)/N + \sin((N-1)t))/\pi \quad (N > 1) \\ & \text{where } t = 2 * \arcsin(\sqrt{x}) \end{aligned}$

### 4.7.4 Simplified Specification of Wagner Functions:

If the only shape functions that the user wishes to apply for a particular run are the first N Wagner functions [5], then the keyword-driven file input description can be dispensed with since the set-up for these functions is easily generated. The only likely reason that the file input might still be preferred is that the given scaling of the variables may prove less than satisfactory. The present automated scheme generates all of the scale factors from a "seed" entered by the user. The relative scaling for  $N = 1, 2, 3, 4, 5, \dots$  at the time of writing is 1, 1, 1, 1, 1, 3, 3, 3, 3, 3, 10, 10, 10, 10, 10, 30, 30, 30, 30, 30, 100, 100, ..., based on very little empirical evidence. Such values should be established more systematically than experience has permitted so far, though optimal scaling in general is an open question. See "Choice of Scale Factors" below.

### 4.7.5 Quasi-Newton Method For Nonlinear Optimization:

The nonlinear optimization algorithm adopted here is that developed by Kennelly for program FLOGQNM [4], itself a refinement of the QNMDIF implementation of Gill, Murray, et al. [1]. Only a brief outline of this revised quasi-Newton method can be provided here. QNMDIF, in combination with the algorithm of subroutine FDSTEP (below), is a modern, robust, and efficient package for the unconstrained minimization of functions (not necessarily sums of squares) of N variables. It uses finite difference approximations for first derivatives, which in turn

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are used to build, through successive updates, a matrix having Hessian-like properties. (The Hessian for a function of  $N$  variables is the  $N \times N$  matrix of second derivatives.) The approximate gradient and Hessian are used to compute a Newton-type search direction at each step, with descent ensured by controlling the positive-definiteness of the matrix via its Cholesky (LDL') factors.

A safeguarded line search routine chooses adequate step lengths efficiently, with account taken of functions that are calculable to less than full machine precision, and automatic switching between forward and central differencing in response to function behavior.

This package is appropriate for the present application since analytic derivatives of the objective function are almost as out of the question as they are in the case of target pressure distributions. Furthermore, a good general-purpose package tends to behave as well as, or better than, typical packages specially adapted to sum-of-squares-type functions. Also, the relative simplicity of an unconstrained algorithm is preferred to a general constrained algorithm, since the only likely constraint is one on thickness, which can be handled with a penalty function (below).

Experience so far suggests that single precision (32-bit) arithmetic is adequate for QNMDIF to solve reasonable OPTIMIZE problems. The significant QNMDIF parameter settings chosen with no provision for interactive changes include  $ETA=0.1$ ,  $TOL=.001$ ,  $EPSMCH=5.E-8$ , and  $EPSOBJ=EPSMCH*100$ . The initial Hessian-like approximation is a diagonal matrix containing estimates for the subset of second derivative elements provide by the preliminary CENDIF/FDSTEP calculations (based on algorithm FD of [2]), which are not optional either, as they play a large part in QNMDIF's success by estimating optimal finite differencing intervals.

An arbitrary upper limit of 100 optimization iterations is imposed. This can lead to many hundreds of function evaluations if the problem is poorly posed, so the airfoil designer is urged to be careful in setting up the OPTIMIZE option.

Restarting an OPTIMIZE solution is always a possibility. The improved finite difference intervals may make a difference on difficult problems. However, no provision has been made for saving the accumulated curvature information represented by the current Cholesky factors  $L$  and  $D$ , as this application of QNMDIF (to a relatively well-behaved function) is most likely to find solutions in a single run in a modest amount of CPU time.

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### 4.7.6 Choice of Scale Factors:

The scale factors applied to active variables are intended to assist the optimizing algorithm, which behaves best if the solution lies in the unit sphere and the rows of the Hessian matrix of second derivatives at the solution are approximately equilibrated. (Ideally, the function should not exceed unity in the unit sphere, but it may not be possible to meet any of these criteria.) Many aspects of the scaling problem are discussed in [1] and [2]. To some extent, less-than-ideal scaling is handled satisfactorily by the dynamic selection of intervals for finite differencing by routines CENDIF and FDSTEP.

### 4.7.7 Choice of Target Thickness And Penalty Parameter:

OPTIMIZE prompts the user for a target maximum thickness ratio (as a percentage of chord). Unlike the REFIN option, it cannot guarantee this target thickness precisely. The target is used in a penalty function of the form

$$\langle \text{penalty parameter} \rangle * ( \text{current \% T/C} - \text{target \% T/C} )^{**2}$$

which is added to the rest of the sum-of-squares-type objective function. The user can seek the same thickness as the original airfoil by entering just a carriage-return (but it is unlikely to be retained precisely). The user can also choose to suppress the constraint by entering either zero or a carriage-return in response to the prompt for the penalty parameter. This can save CPU time, because the thickness calculation is then avoided. In practice, however, the presence of a constraint of this nature can actually speed the convergence of the optimizing algorithm, which isn't to say that the target curvatures will be matched any better. QNMDIF should find a minimum, but there is nothing to stop the user from reformulating the problem if he doesn't like the best fit that was found.

In principle, successive runs of OPTIMIZE with increasingly larger values for the penalty parameter can produce the desired thickness, but the availability of the much more precise, and cheap, REFIN option argues for an OPTIMIZE run with, say, penalty parameter = 100., followed by a refinement run (with numerous options open) if the thickness is required to be some precise value.

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### 4.7.8 Comparison of Curvature With The Target Distribution:

The same table-look-up with linear interpolation that was implemented for the REFINE option's target  $y''$  requirements is used in routine CFDISTRIB. This means that, in principle, the target and current curvature distributions do not have to be defined at the same abscissas, though in practice it is most likely that the two sets of abscissas will be identical. No attempt has been made to weight the elements of the sum of squares, in the interest of simplicity.

### 4.7.9 Displaying Results:

The user is prompted for minimal or comprehensive output of QNMDIF's progress. Normally, brief output should be all that is needed. Upon termination of PROFILE, the recommended sequence is as follows (where <ident> refers to the identifier prompted for at the beginning of the PROFILE run):

```
QPLOT <ident>.PLT ... revised-versus-original airfoil plot
QPLOT <ident>.CRV ... upper/lower, old/new curvature plots
PRINT <ident>.TAB ... tabulations of the original airfoil,
                        the target information, bump function
                        description, CENDIF results, QNMDIF
                        results, and the revised airfoil.
```

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### 5.0 REFERENCES

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5. Ramamoorthy, P. and K. Padmavathi. "Airfoil Design by Optimization" in J. Aircraft, Vol. 14 (Feb. 1977), 219-221.
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# APPENDIX A: Related Software (1): BPLOT

Program BPLOT generated the data for the perturbing function plots shown in APPENDIX C. As with PROFILE, it was developed on a VAX under VMS. It employs the same GETBUMPS routine that is part of PROFILE's OPTIMIZE option. This means that the "bumps" are either prepared first in a text file, as described in 4.7, or they are the first N Wagner functions, which can be plotted without such a file.

Perhaps the most useful application of BPLOT is to checking the subset of perturbing functions that are about to be used in an airfoil optimization run (of either PROFILE's OPTIMIZE, or FLOSONM, or similar design codes). Proper choice of the bump subset is one of the elements crucial to success with the optimizing algorithm, and such a visual aid might save some grief. Noteworthy features of BPLOT include the following:

- Perturbing functions are selected by name (family).
- If all functions in the subset to be plotted are from the same family, BPLOT automatically generates the plot title from the name of the family, and the plot subtitle from the corresponding formula. Otherwise, the user is prompted for a suitable title (with no subtitle).
- Any unit MULTIPLIERS are suppressed, as this gives more room in the legend that is constructed by BPLOT to make the plot as self-descriptive as possible.
- All functions in the subset are plotted on the same frame, and only one frame is produced per run of BPLOT.
- BPLOT prompts for all its inputs - no additional control file is used, and no logical unit assignments are necessary prior to running it.
- An arbitrary limit is imposed on the number of abscissas in the range [0,1] at which each function is evaluated. This limit was 200 at the time of writing. BPLOT allows the user to choose a coarser grid if that will suffice, leading to better turn-around. (Generating the plottable data is fast; plotting the results can be slow.)
- As with PROFILE's plots of curvature, BPLOT's plots are actually produced by program QPLOT, which is described in the next appendix.

## PROFILE User's Guide (Appendix A)

A sample input dataset, with corresponding QPLOTtable output dataset, is shown below. Note that BPLOT takes advantage of some of DISPLA's (and hence QPLOT's) embedded-command capabilities in its generation of the legend information. See Section 4.7 for a description of the keywords used here. Remember: just one BUMP or bump-variable keyword per line. (The STATUS and SCALE keywords needed by PROFILE's OPTIMIZE option would be ignored by BPLOT if present. They have been omitted in the sample to avoid confusion.)

### Sample Input File For BPLOT:

```
BUMP: EXP
POWER: 0.1
WIDTH: 10.0
MULT: 1.0

BUMP: EXP
POWER: 0.2
WIDTH: 10.0
MULT: 1.0

BUMP: EXP
POWER: 0.4
WIDTH: 10.0
MULT: 1.0

BUMP: EXP
POWER: 0.6
WIDTH: 10.0
MULT: 1.0

BUMP: EXP
POWER: 0.8
WIDTH: 10.0
MULT: 1.0

BUMP: EXP
POWER: 1.0
WIDTH: 10.0
MULT: 1.0
```

# PROFILE User's Guide (Appendix A)

Corresponding Output File From BPLOT:

```
[EH1.4]EXPONENTIAL
[L.8]*[LX]POWER[L.8](1-x) *([LX]-WIDTH[L-.25]*[LX])*
X/C
Shape function
$OPTIONS
GRID = 0.
LEGEND = '[F0H.8]POWER 0.100 WIDTH 10.000'
LINE = 'SOLID'
$END
0.000000 0.000000
0.071429 0.349134
0.142857 0.169092
0.214286 0.079019
:
:
1.000000 0.000000
$OPTIONS
GRID = 0.
LEGEND = '[F0H.8]POWER 0.200 WIDTH 10.000'
LINE = 'DASH'
$END
0.000000 0.000000
0.071429 0.268151
0.142857 0.139192
:
:
1.000000 0.000000
$OPTIONS
GRID = 0.
LEGEND = '[F0H.8]POWER 0.400 WIDTH 10.000'
LINE = 'DOT'
$END
0.000000 0.000000
0.071429 0.158181
:
:
1.000000 0.000000
$OPTIONS
GRID = 0.
LEGEND = '[F0H.8]POWER 0.600 WIDTH 10.000'
LINE = 'CHAINDASH'
$END
0.000000 0.000000
:
:
```



PROFILE User's Guide (Appendix A)

```

1.000000 0.000000
$OPTIONS
GRID = 0.
LEGEND = '[F0H.8]POWER 0.800 WIDTH 10.000'.
LINE = 'CHAINDOT'.
$END
0.000000 0.000000
:
:
1.000000 0.000000
$OPTIONS
GRID = 0.
LEGEND = '[F0H.8]POWER 1.000 WIDTH 10.000'.
LINE = 'SOLID'.
$END
0.000000 0.000000
:
:
1.000000 0.000000

```

## PROFILE User's Guide (Appendix B)

### APPENDIX B: Related Software (2): QPLOT

Program QPLOT produced the plots of curvature data from PROFILE, shown in Appendix D, and the plots of perturbing function data from program BPLOT, shown in Appendix C. BPLOT is a good illustration of how the use of QPLOT can keep the actual plotting out of the program generating the data. (The same is true of the later versions of PROFILE - QPLOT is also used to plot the airfoil geometry (to scale), where this had originally been done by PROFILE itself.) QPLOT and BPLOT were both developed under the same contract as PROFILE.

QPLOT is a general-purpose plotting package suited to the bulk of every-day applications, with minimal knowledge of graphics required on the part of the user. It handles any number of curves on a frame, with self-scaling as the default, and any number of frames per run. Titles and labels precede the data (typically two columns of numbers, though QPLOT can select from more than two); an optional NAMELIST provides legends, specific scaling, and so on, if these are desired. QPLOT runs on a VAX under VMS, and is built around the DISPLA package of ISSCO. (DISPLA is proprietary and not available for normal distribution from NASA.)

Those in possession of PROFILE, BPLOT, and QPLOT should find broader application for QPLOT, so the following description, sample input data sets, and corresponding plots, are included for completeness.

PROGRAM QPLOT

Description and usage:

This program is intended for "generic" DISPLA plots with minimal user involvement. The number of curves per plot is (almost) unlimited, and any number of plot frames may be produced in one run if the appropriate separator is used between the data sets. The plot parameters are fully defaulted - a minimal input file consists of two columns of numbers and will produce a reasonable-looking plot of a single curve. Multiple curves or frames, titles and legends, scaling, grids, etc. are all possible but strictly optional. Blank lines anywhere in the input file are ignored.

The input file consists of the following:

- (a) A plot title, subtitle, and labels for the X and Y axes, each on a separate line. No subtitle will appear unless there is a title, and both axes must be labeled if one of them is. A dollar sign may be used as a place-holder, or for positioning a string within a field of blanks. Special character sets are available - see Notes below.
- (b) An optional namelist denoted OPTIONS, which may be used to override the default plot size, axis scaling and line type, add legend entries, create a background grid, or specify the columns from which the data is to be read. Comments may also be included, but will not appear in the plot. The namelist must precede the data for each curve.
- (c) The data to be plotted in multi-column format. If more than one curve is to be plotted, each set of data points must be followed by an OPTIONS namelist or a line beginning with "END CURVE." The columns of data may be separated by blanks, tabs, commas, colons, or equal signs (see SCANNER header for details).
- (d) The final curve of a frame must be terminated by a line beginning with "END FRAME" if more data is to follow.

This version is set up for a maximum of 100 curves. The number of points per curve is arbitrary, but the total number of points per frame must not exceed 10,000. There is no limit on the number of frames.

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# PROFILE User's Guide (Appendix B)

There are two output files: logical unit LWRITE receives error and completion messages, including those from DISSPLA, while the plot file is sent to unit LPLOT (in NASA-Ames DIP format). The DIP file must be post-processed to create the actual plot.

At NASA-Ames, a number of companion utilities are available. An input file may be created interactively with program IQPLOT. Procedure DIPTXK is available for previewing multiple frame plots on a "green screen" graphics terminal (Retrographics VT640), and a special command, GREEN, is available for automatically invoking QPLOT and displaying a single plot frame on a graphics terminal. Use DIPVRC to make a Versatec hardcopy.

## Input data:

Name	Type	Description
TITLES	C	Plot title and axis labels. Max. 80 characters each. The number of characters which will fit on a line is less than this (40 is typical) - the higher limit permits inclusion of special instructions if needed. Interpretation of the input depends on the number of lines of text found, as follows:

- 0 lines => no titles or labels
- 1 line => single title
- 2 lines => title and subtitle
- 3 lines => title and X, Y axis labels
- 4 lines => title, subtitle, and X, Y axis labels

X,Y	R	A '\$' may be used as a terminator. Embedded square brackets '[' and ']' have special significance for alternative character sets - see Notes. Plot data arranged in a vertical columns. Default correspondences are X = col. 1, Y = col. 2.
-----	---	---

## NAMELIST input data:

/OPTIONS/ (NOTE - This NAMELIST may be freely omitted!)

Name	Type	Description
PLOT	C	Plot type: The default is for linear axes; 'CONVERGENCE' plots a logarithmic vertical scale against linear horizontal; 'SCALE' is for linear axes with equal scaling in both directions.
GRID	I	Number of grid lines per scale division. If 0, a box is drawn around the plot. Default is NO grid.

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The axes are always crossed in the lower left hand corner of the plot if a grid is requested.

Nominal plot dimensions, in inches. Default is 5.5 inches on a side - this is small enough that a viewgraph of a full plot with title, subtitle, legends, etc., will fit a projector comfortably. The maximum dimensions have been limited to 8.75 and 7.00, respectively, to keep everything on the page.

Optional legend entry for each curve. Max. 80 characters, may be terminated with \$. At most 20 legends will appear in the plot. A "blank" legend such as '\$' will appear with a blank text field.

Optional flags to indicate the line type to be used. The default is a solid line with symbols for each curve. Other options are: 'SYMBOLS', 'SOLID', 'DOT', 'DASH', 'CHAINDOT', 'CHAINDASH', and 'THICK'. ('DEFAULT' need not be specified).

Column numbers from which X and Y data are to be read. Defaults are XCOL = 1, YCOL = 2. If XCOL or YCOL are zero, the ordinals i = 1, 2, 3, ... will be used.

Optional X axis scaling limits. The actual limits may be rounded off by DISSPLA to "nice" values. By default, axis limits will be calculated by QUICK.

Optional Y axis scaling limits. Default is automatic scaling, as for the X axis. Choose YMIN > YMAX for an inverted axis.

#### Input format:

Sample Plot Title  
Optional subtitle  
X (horizontal) Axis Label  
Y (vertical) Axis Label

← The first four lines of text are optional, but must be in order.

\$OPTIONS  
YMIN = 0.0,  
YMAX = 10.0,  
LINE = 'SOLID',  
\$END

← The NAMELIST is optional. It must begin in col. 2.

← Note that CHARACTER type inputs via NAMELIST must be enclosed in quotes.

6.3  
4.5  
8.9  
5.8  
2.4

← Columns of data may be separated by spaces, tabs, commas, colons, or equal signs.

# PROFILE User's Guide (Appendix B)

```

1,3
END CURVE
$OPTIONS
XCOL = 3, 'Curve #2',
LEGEND = 'Curve #2',
$END
.546 .53472 .234
.123 .76598 .345
(etc.)
.23646 5.465457 1.46474
END CURVE
(etc.)

```

<— "End-of-curve" mark (not required if next curve has NAMELIST.  
 <— Multiple column input.  
 <— If "END FRAME" is used here instead, the entire data set input format may be repeated.

## External files:

Unit	I/O/S	Description
5	I	Input file ("card reader").
6	O	Output file ("line printer").
9	O	Plot file in DIP format.

## External references:

Name	Description
ALPHA	Distinguishes alphabetic from purely numeric data.
DIP	Sets up DISSPLA plot file in DIP format.
DONEPL	Closes plot file.
EXIT	Stops execution. See Notes below.
IOCHECK	Returns LOGICAL I/O flags.
NLCHEK	Identifies legal or suspicious NAMELISTs.
QUICK	Plot driver which calls DISSPLA routines.
RDCOLS	Reads a "curve" to be plotted, in multi-column format.
TERMIN	Adds a mark ('\$' here) to the end of a string.
UPCASE	Converts a string to uppercase.

Environment: Digital VAX-11/780 VMS FORTRAN 77.

## Notes:

- (1) IMPLICIT NONE is non-standard.

# PROFILE User's Guide (Appendix B)

- (2) NAMELIST input is non-standard. The VAX NAMELIST symbol is \$ or &. All NAMELIST input must begin in column 2. Spaces, tabs, or commas are valid separators. The data may appear in any order. It is not necessary to assign values to all of the NAMELIST input variables.
- (3) CALL EXIT (N) is VAX-specific. A parameter value of 1 indicates successful completion, while 3 is defined here to mean abnormal termination. These values are available to the system after the end of the run.
- (4) The OPEN statement for the input data file contains the VAX-specific parameter READONLY, which permits input across different accounts.
- (5) A large variety of type sizes and styles are available. See Part B, Section 24 of the DISPLA manual for details on the 'INSTRUCTION' alphabetic commands. The escape to the special command set is the left square bracket '[' and the return is signaled by ']' - these characters can therefore only appear in a title by specifying them from the mathematical set, for example.
- (6) Drastic re-sizing (using HEIGHT and WIDTH) may require changes in character sizes or spacing. This may be done by embedding the appropriate directives in the input strings, or more generally, by modifying a copy of plot routine QUICK and re-linking. See command procedure QPLOTLINK.COM for an example.
- (7) The "dummy variables" declared below, and included in /OPTIONS/, are provided for a degree of input compatibility with QMOD, another plotting program derived from QPLOT but using a different graphics package. They may (and should) be removed in any context where not required.

Author: Robert Kennelly, Informatics General Corporation.

## Development history:

14 May 1982	RAK	Original design and coding.
29 Sep. 1982	RAK	Drives multiple-plot version of QUICK.
29 Nov. 1982	DSM	Allows multiple curves per plotframe.
31 Dec. 1982	RAK	Restructured for proper termination.
17 Feb. 1983	RAK	Modified to permit axis scaling and line type inputs.
28 Feb. 1983	RAK	Generalized TYPE input.
23 Mar. 1983	RAK	Fixed input bug - was skipping too many

# PROFILE User's Guide (Appendix B)

C			lines when OPTIONS was absent.
C	2 June 1983	RAK	Added explicit OPEN statements (except for unit 9, which is handled by DIP).
C	13 June 1983	RAK	Added provision for multiple frames per run.
C	24 June 1983	RAK	Added a BACKSPACE for when NAMELIST is absent (bug), corrected defaulting, spruced up READ protection.
C	3 Nov. 1983	RAK	Updated IOCHECK parameter list (CONVER).
C	13 Feb. 1984	RAK	Extensive revisions. Added legends, grid, multiple column input, more line type options, etc. More error recovery is done in RDCOLS.
C			New packed data structure for X, Y arrays.
C	23 Feb. 1984	RAK	Added subtitles, with all titles now optional.
C	13 Mar. 1984	RAK	COMMENTS now permitted in the namelist.
C			Added namelist inputs HEIGHT and WIDTH.
C			Eliminated ECHOing of input data. Legend strings are packed in a CHARACTER variable.
C	23 Apr. 1984	RAK	Corrected counting of titles when blank found. Any blank line (anywhere) is now ignored.
C			A number of QMOD variables are declared and included in the namelist for compatibility.
C	11 May 1984	RGL	Added capability for a logarithmic vertical axis in the form of namelist option PLOT, derived from COMPLT.
C			Minor tidying up. PLOT is converted to upper case and checked for legality before calling QUICK. Added protection against invoking the plot routine with no data.
C			Reordered namelist data packing to allow curves with no data to be ignored. RDCOLS arguments reordered.
C	18 June 1984	RAK/DAS	



# PROFILE User's Guide (Appendix B)

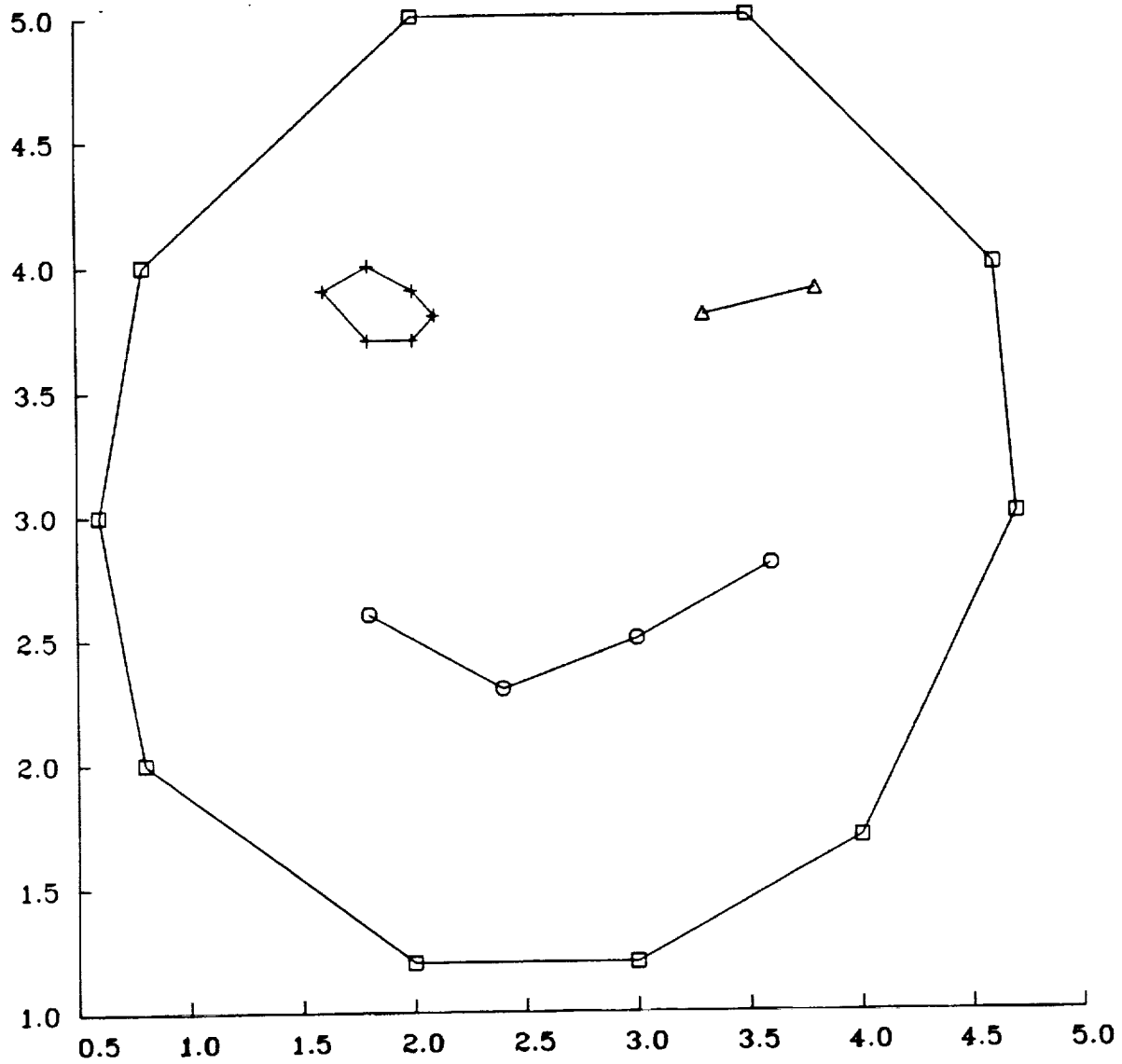
## Plain QPLOT Example

```

2 1.2
3 1.2
4 1.7
4.7 3
4.6 4
3.5 5
2 5
.8 4
.6 3
.8 2
2 1.2
END CURVE
1.8 2.6
2.4 2.3
3 2.5
3.6 2.8
END CURVE
3.3 3.8
3.8 3.9
END CURVE
2 3.7
2.1 3.8
2 3.9
1.8 4
1.6 3.9
1.8 3.7
2 3.7
END FRAME

```

## Plain QPLOT Example



Fancy QPLOT Example  
 Look, look! A rather long-ish subtitle is now optional.

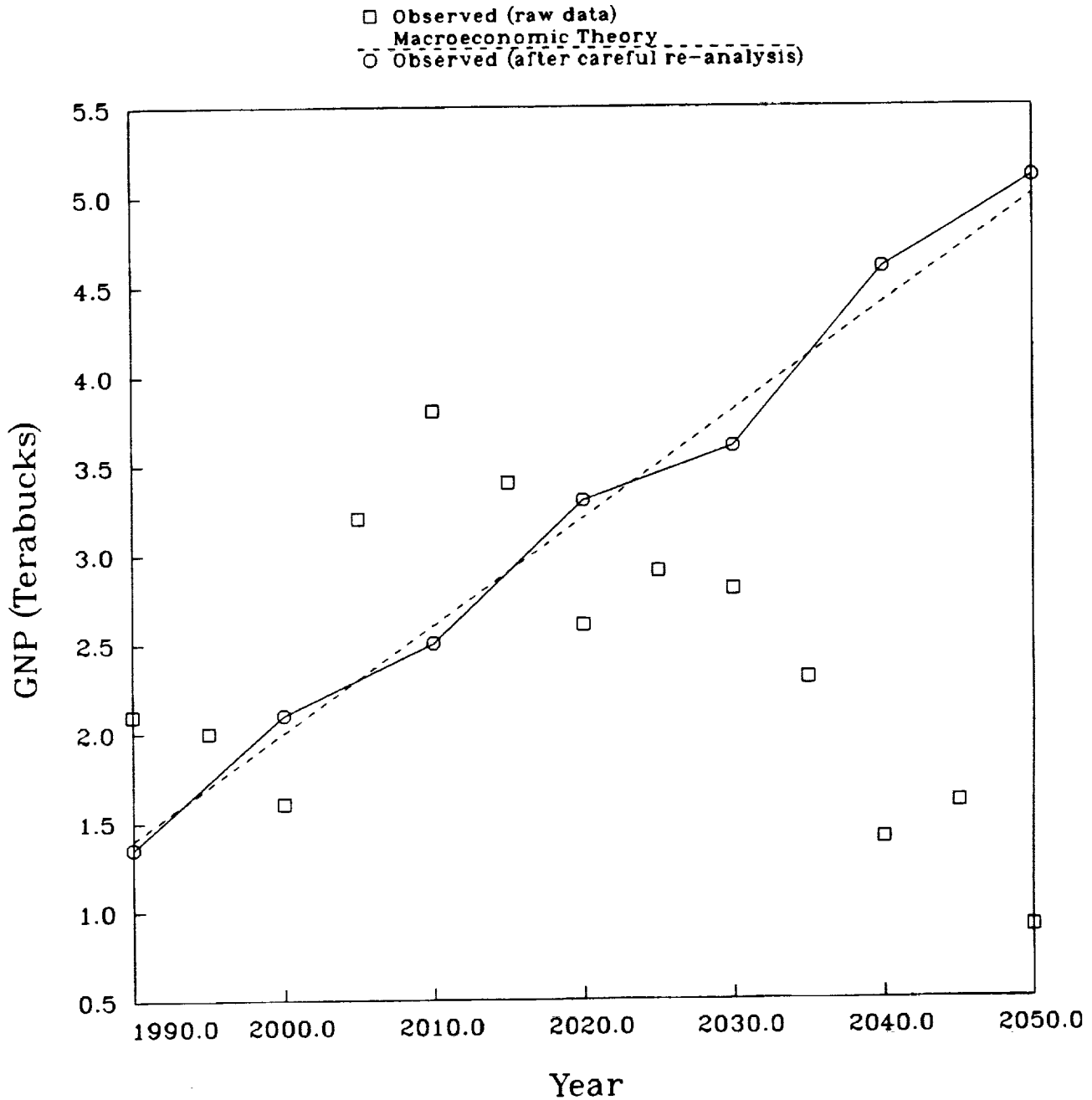
```

Year
GNP (Terabucks)
$options
grid = 0,
xcol=2,ycol=3,
legend = 'Observed (raw data)',
line = 'symbols',
$end
123 1990 2.1
123 1995 2.0
...
123 2050 .9
$options
xcol=2,ycol=3,
legend = 'Macroeconomic Theory',
line = 'dash',
$end
456 1990 1.4
456 2000 2.0
...
456 2040 4.4
$options
xcol=2,ycol=3,
legend = 'Observed (after careful re-analysis)',
$end
789 1990 1.35
789 2000 2.1
...
789 2050 5.1
end frame

```

## Fancy QPLOT Example

Look, look! A rather long-ish subtitle is now optional.



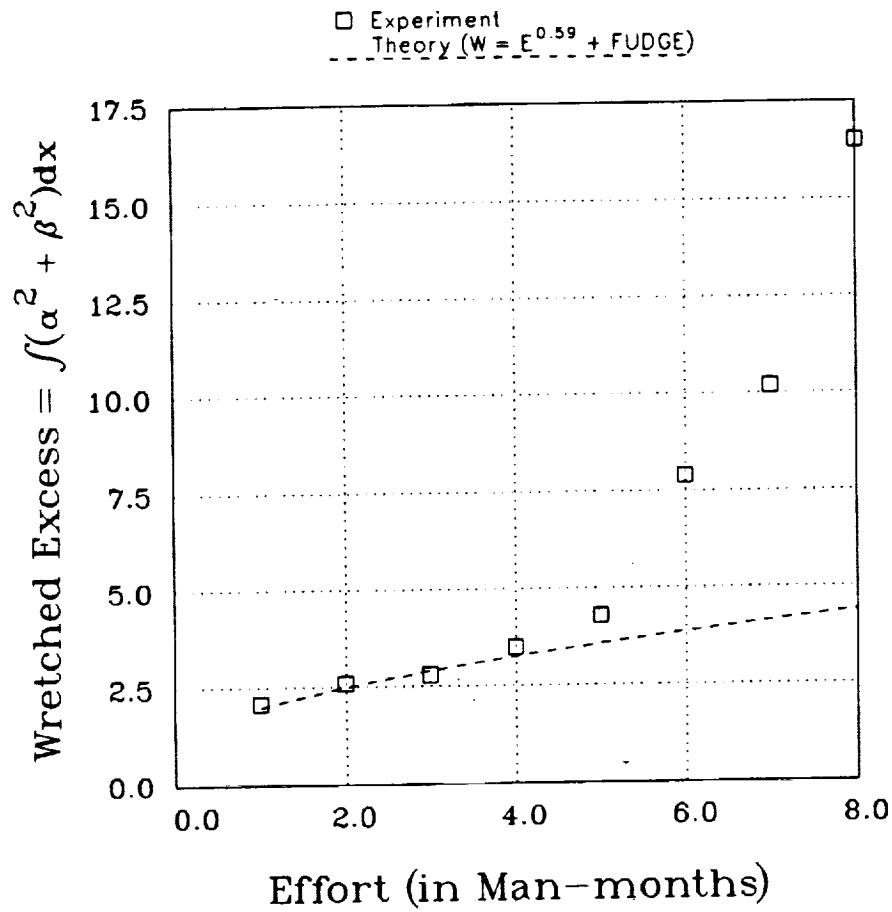
# PROFILE User's Guide (Appendix B)

```
[H2.0FGM2]Ultimate OPLOT Example
[H1.2MG]Tic is a pcony Greek subtitle[U]
Effort (in Man-months)
Wretched Excess = [M11]1([M6H.8]a[E]2[EX] + b[E]2[EXMX]))dx
$Options
height = 3.5, width = 3.5,
xmin = 0, ymin = 0,
grid = 1,
xcol = 0, ycol = 1,
line = 'symbols',
legend = '[F2]Experiment',
comment = 'this is a comment - it does not appear in the plot',
$end
2.1
2.6
...
16.5
$Options
xcol = 0, ycol = 1,
legend = '[F2]Theory (W = E[PH.7E]0.59[HXEX] + FUDGE)',
line = 'dash',
$end
2.0
2.51
...
4.41
```

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# Ultimate QPLOT Example

Τηλοισαπηνψ Γρεεκ συβτιτλε



## PROFILE User's Guide (Appendix C)

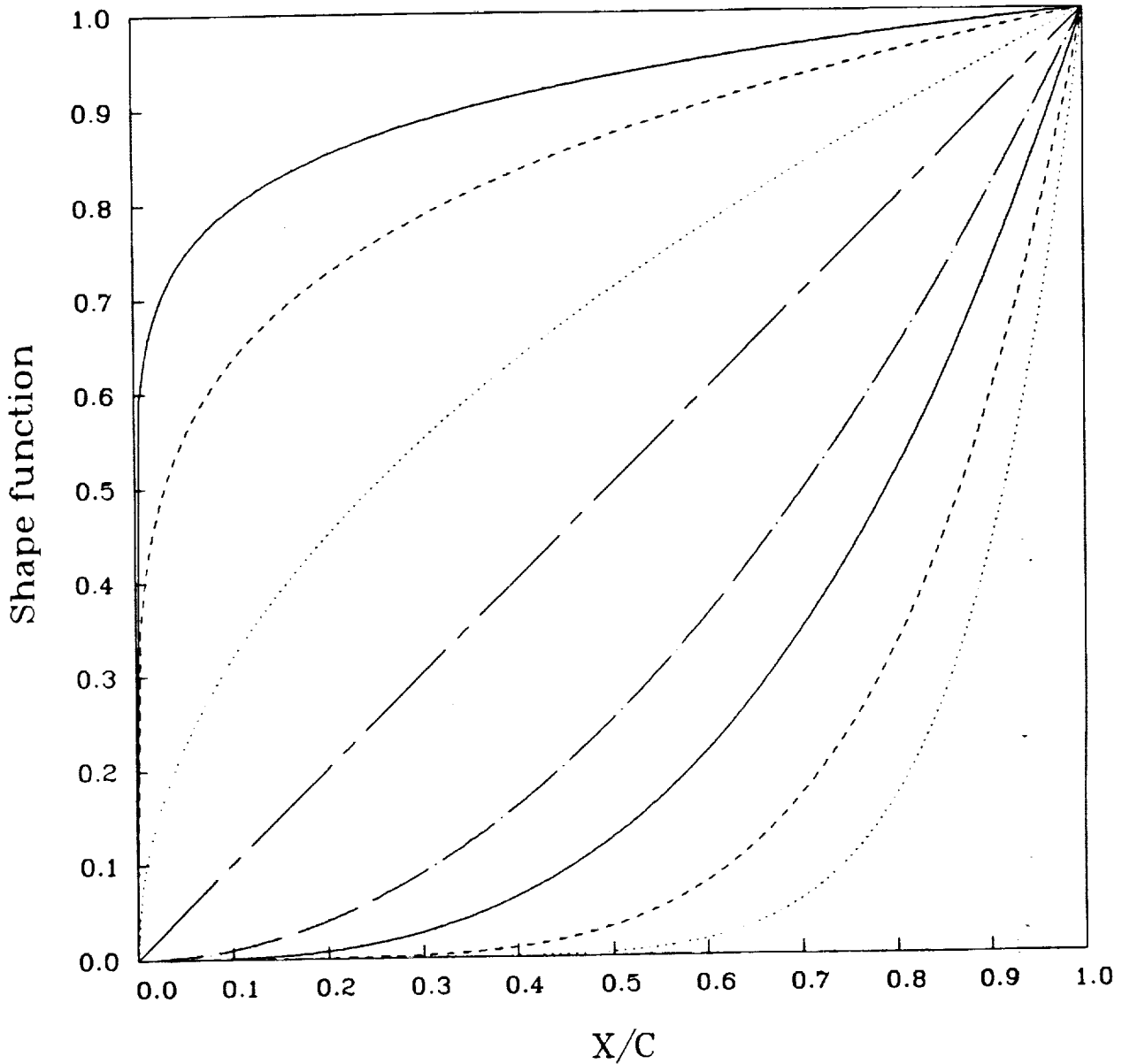
### APPENDIX C: Perturbing Function Illustrations

The following plots of representative airfoil shape functions were generated by programs BPLOT and QPLOT.

# TRAILING

$x^{\text{POWER}}$

POWER	0.100	POWER	2.000
POWER	0.200	POWER	3.000
POWER	0.500	POWER	5.000
POWER	1.000	POWER	8.000



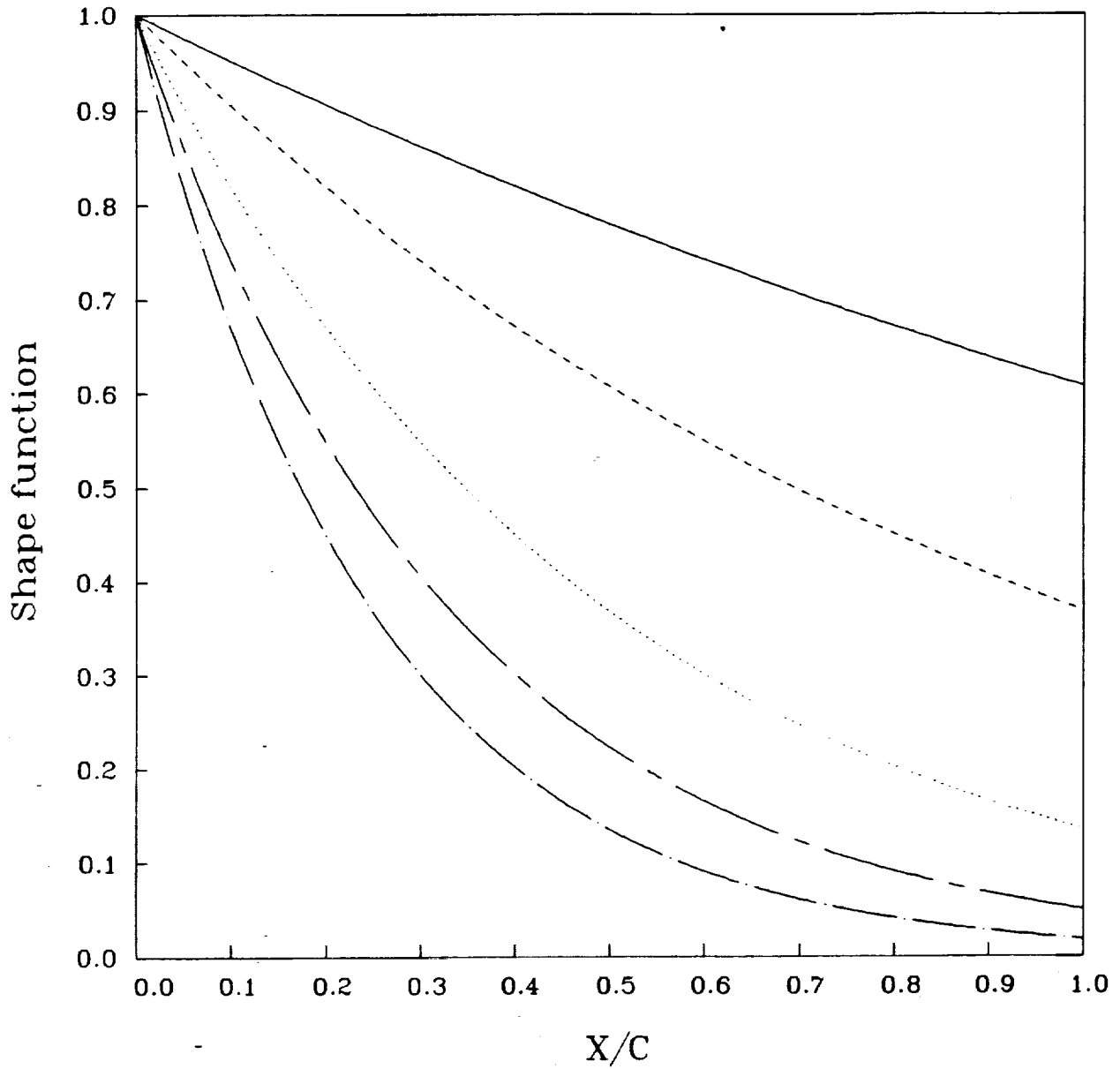
PLU1 1 18.15.53 MON 19 NOV, 1984 JMB-BK1#FIL3, NASH/H 0155FLR 9.2



# DROOP

$$e^{-\text{WIDTH} \cdot x}$$

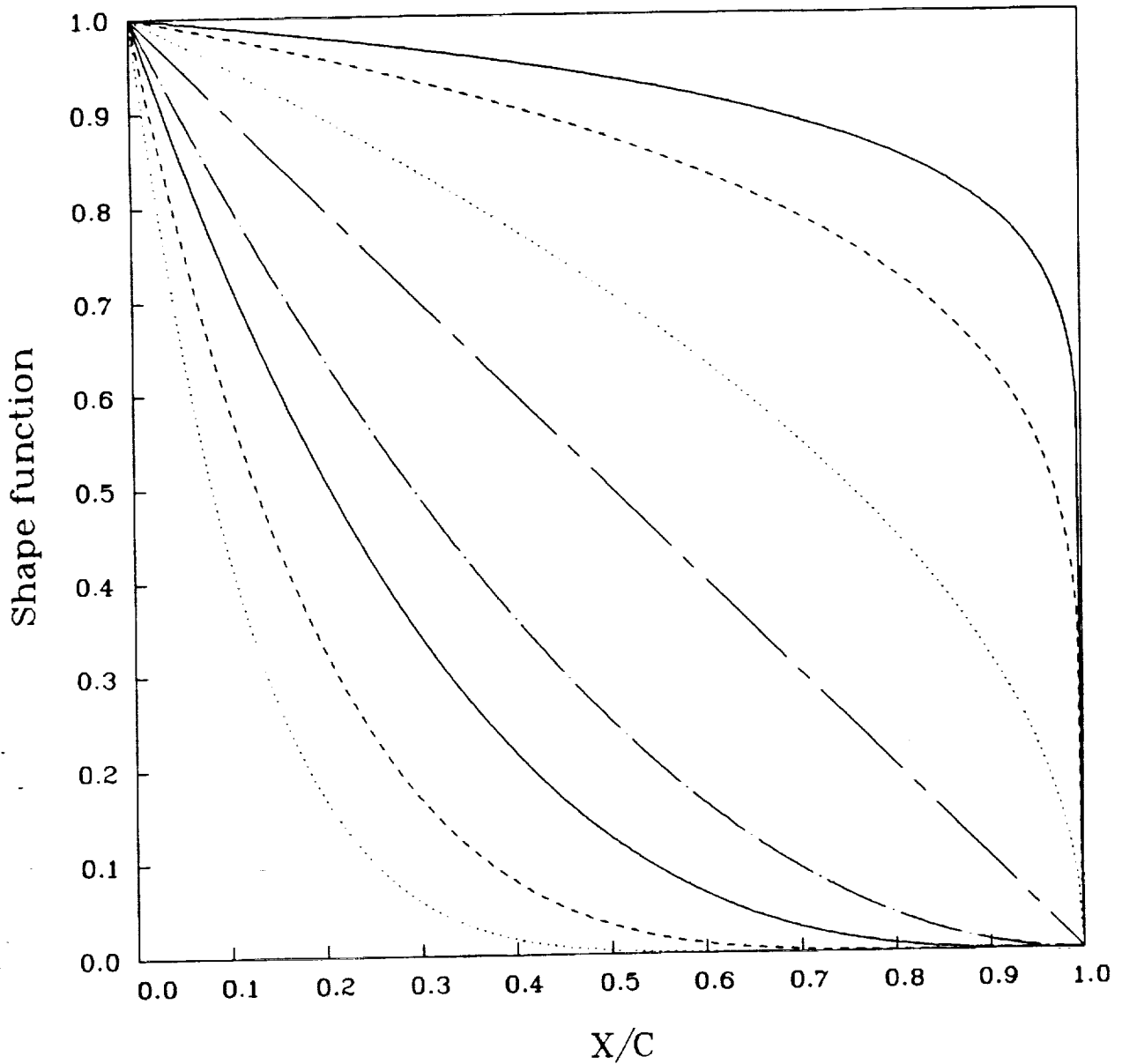
WIDTH	0.500
WIDTH	1.000
WIDTH	2.000
WIDTH	3.000
WIDTH	4.000



# LEADING

$$(1-x)^{\text{POWER}}$$

POWER	0.100	POWER	2.000
POWER	0.200	POWER	3.000
POWER	0.500	POWER	5.000
POWER	1.000	POWER	8.000

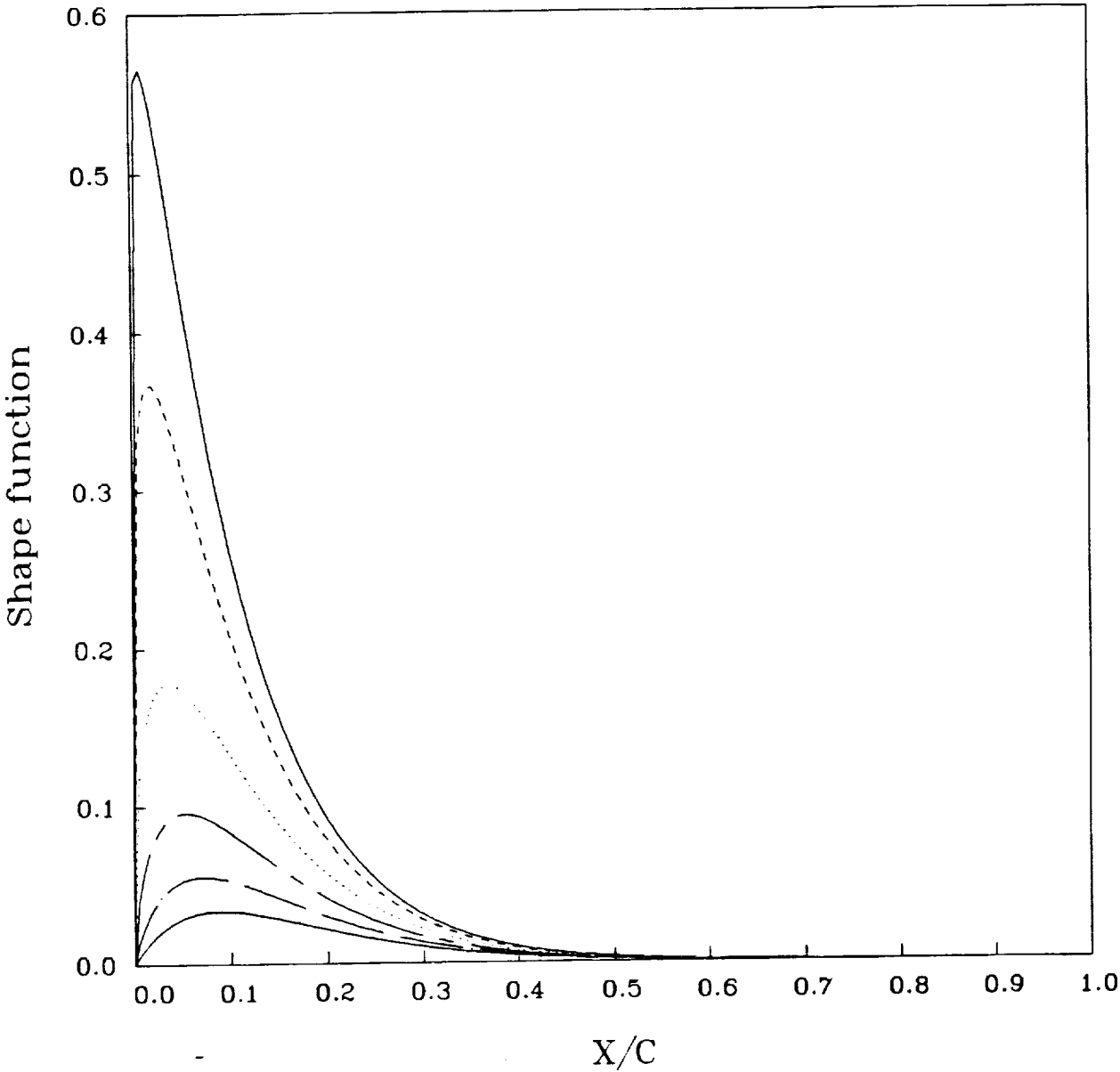


# EXPONENTIAL

$$x^{\text{POWER}}(1-x) e^{-\text{WIDTH} \cdot x}$$

POWER	0.100	WIDTH	10.000
POWER	0.200	WIDTH	10.000
POWER	0.400	WIDTH	10.000

POWER	0.600	WIDTH	10.000
POWER	0.800	WIDTH	10.000
POWER	1.000	WIDTH	10.000

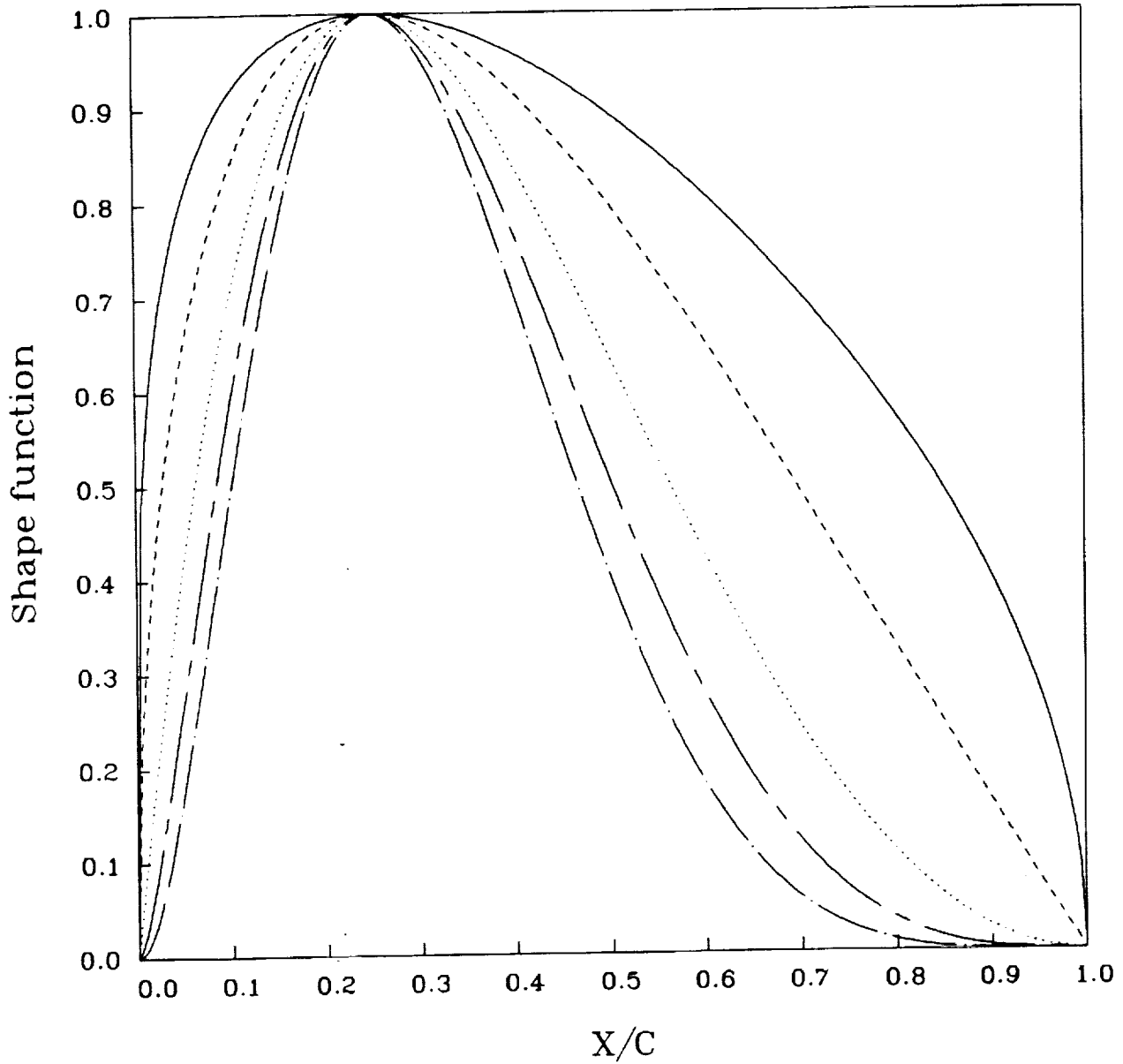


PLU1 1 10.10.40 RUN 19 NOV, 1984 JOB=GRAPHICS, NAME=H UIC50504 9.2

# SINE

$$\sin^{\text{WIDTH}}(\pi \times \log 0.5 / \log \text{CENTER})$$

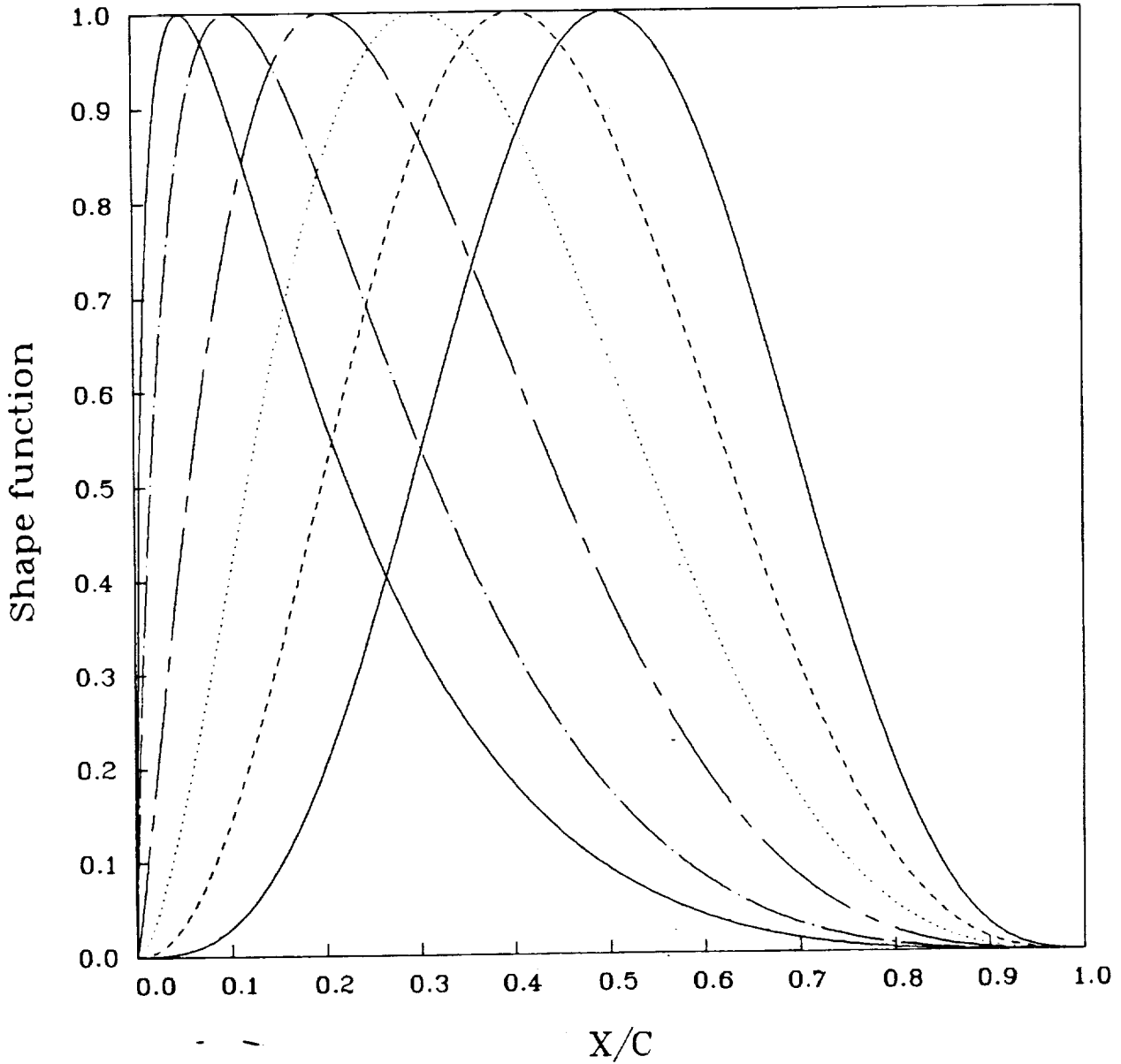
CENTER	0.250	WIDTH	0.500
CENTER	0.250	WIDTH	1.000
CENTER	0.250	WIDTH	2.000
CENTER	0.250	WIDTH	3.000
CENTER	0.250	WIDTH	4.000



# SINE

$$\sin \text{WIDTH}(\pi \times \log 0.5 / \log \text{CENTER})$$

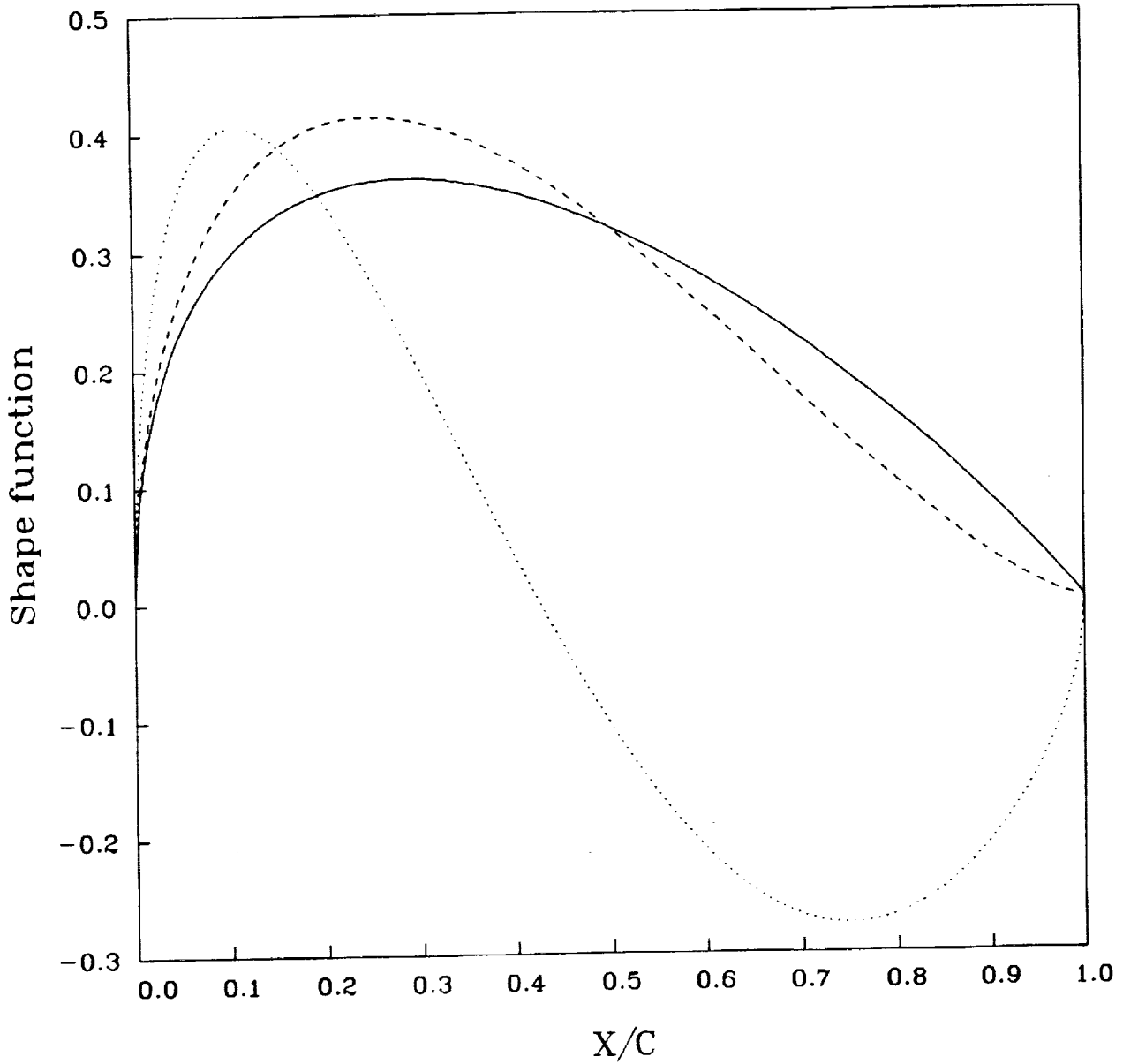
CENTER	0.500	WIDTH	3.000	CENTER	0.200	WIDTH	3.000
CENTER	0.400	WIDTH	3.000	CENTER	0.100	WIDTH	3.000
CENTER	0.300	WIDTH	3.000	CENTER	0.050	WIDTH	3.000



# WAGNER

$$(\sin(Nt)/N + \sin((N-1)t))/\pi; \quad t = 2 \sin^{-1}\sqrt{x} \quad (N>1)$$

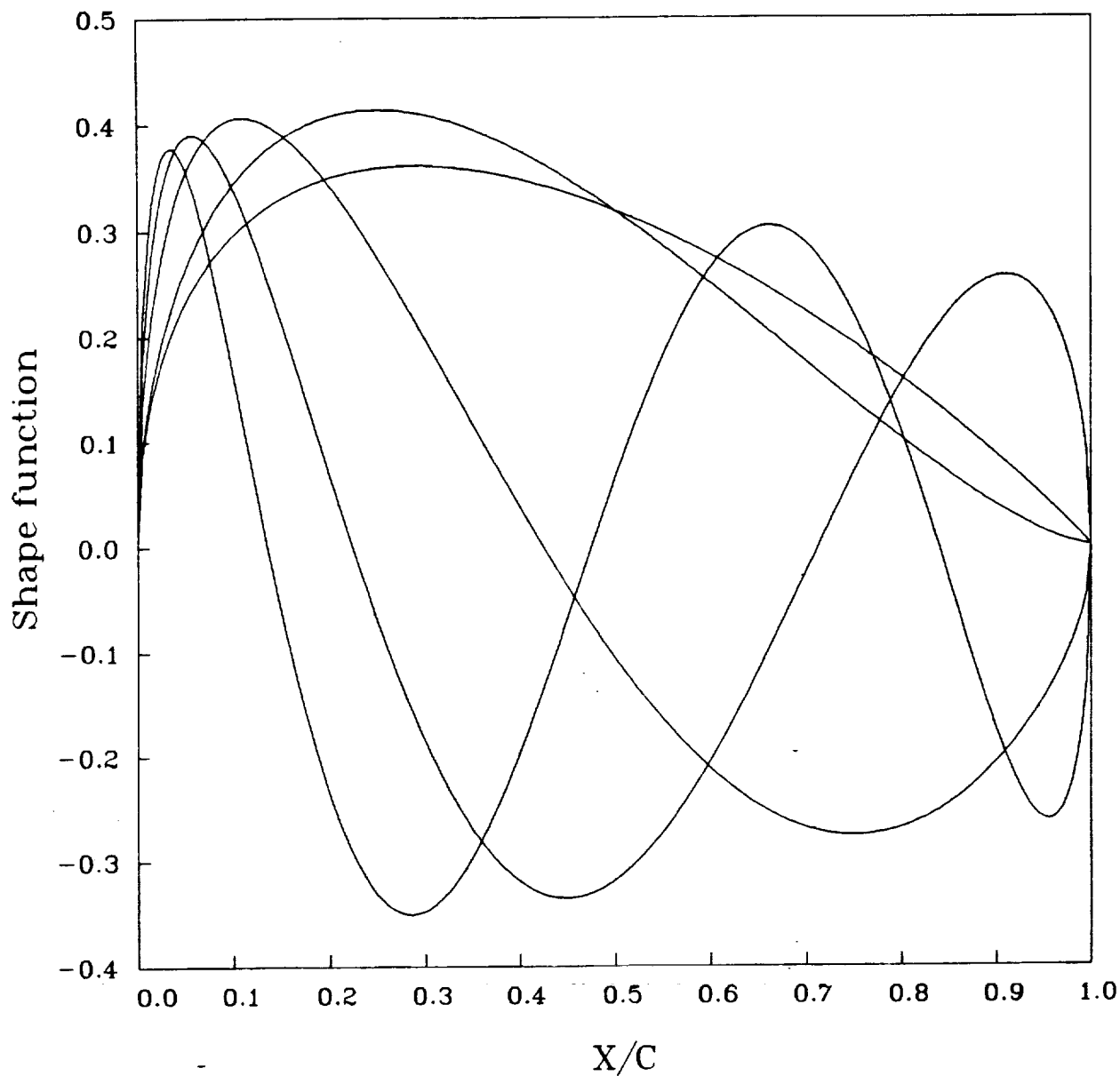
$$\begin{array}{l} N = 1 \\ -N = 2 \\ -N = 3 \end{array}$$



# WAGNER

$$(\sin(Nt)/N + \sin((N-1)t))/\pi; \quad t = 2 \sin^{-1}\sqrt{x} \quad (N>1)$$

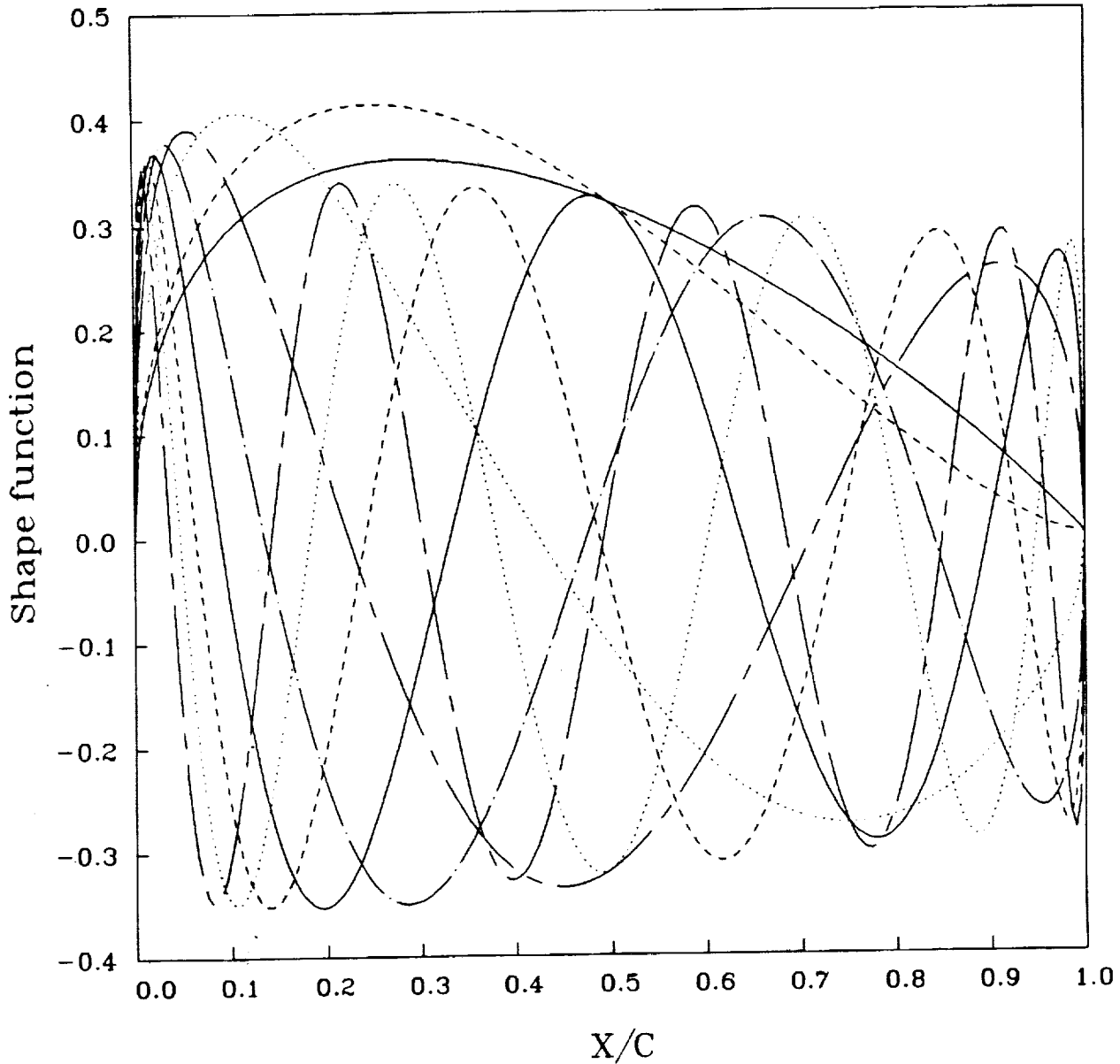
<u>N = 1</u>
<u>N = 2</u>
<u>N = 3</u>
<u>N = 4</u>
<u>N = 5</u>



# WAGNER

$$(\sin(Nt)/N + \sin((N-1)t))/\pi; t = 2 \sin^{-1}\sqrt{x} \quad (N>1)$$

<u>N = 1</u>	<u>N = 6</u>
<u>N = 2</u>	<u>N = 7</u>
<u>N = 3</u>	<u>N = 8</u>
<u>N = 4</u>	<u>N = 9</u>
<u>N = 5</u>	





APPENDIX D: Sample PROFILE Terminal Sessions With Results

All the sample results shown here contain tabulated output (i.e. <identifier>.TAB) files. Since these results include original and/or revised airfoil coordinates, derivatives and curvatures, the other output files are not shown in most cases. The tabulations are abbreviated in some cases where the information is redundant. A sample airfoil geometry QPLOT file is included in example 5. A few sample plots are shown as well.

Sample terminal sessions include screen output with typical user responses.

An empty input control file was used for most runs, because all the defaults were taken and some sort of input control file is required.

Examples 2 through 5 show a sequence of revisions of the same airfoil. Notice how the revised data file from one run of PROFILE is used as input to the subsequent run.

# PROFILE User's Guide (Appendix D, Sample 0)

## (0) NACA 6-Series Airfoil - Mode 0 (plots/tabulations)

The NACA 6-series airfoil used in some of the examples that follow was taken from a program that generates 176 points per airfoil surface. As noted in the description of the REFINE option in this document (see Further Notes on Usage, section 4.6), defining the airfoil on too fine a mesh is to be avoided. This problem is remedied in example 3 with the REDISTRIBUTE option, but for now note the unreasonable curvatures in the sample tabulations file for MODE 0. In fact, the airfoil should have been "rectified" (Mode 1) first, because the finite differencing needed for normal tabulation breaks down if the abscissas are not monotonic. But Mode 0 was desired as a first example here.

---

Sample Terminal Session - no modifications

---

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:

- 0 = default (no modifications) - just plot and tabulate
- 1 = rectify leading edge definition
- 2 = normalize or de-normalize geometry
- 3 = redistribute the abscissas
- 4 = modify - apply shape functions
- 5 = refine thickness/curvature
- 6 = optimize one surface (bumps + target curvatures)

Enter MODE, else <CR> for MODE = 0: <CR>

Enter the PROFILE control file (default is PROFILE.INP):

NACA64412.INP

Enter the airfoil geometry data file (default is AIRFOIL.DAT):

NACA64412.DAT

Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.\*:

NACAMODE0

Enter plot title (up to 80 chars.). <CR> uses PROFILE for the title:

NACA 64412 airfoil

Enter plot subtitle (up to 80 characters) or <CR> if none:

Example 1 MODE 0

Original % thickness: 12.00033 Corresponding X: 0.3790650

Airfoil plot file: NACAMODE0.PLT  
 Tabulated results: NACAMODE0.TAB  
 Curvature QPLOT file: NACAMODE0.CRV  
 2nd derivatives file: NACAMODE0.YPP

# PROFILE User's Guide (Appendix D, Sample 0)

NACAMODE0.TAB file (tabulated coordinates, derivatives and curvatures)

Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

Operating mode: 0  
Control file : NACA64412.INP  
Geometry file : NACA64412.DAT  
Output file id: NACAMODE0  
Profiles found: 1

NACA 64412  
Original upper surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	-0.183760E+02	0.000000E+00	0.000000E+00
-0.125000E-03	0.229700E-02	0.121104E+03	-0.223168E+07	-0.125635E+01
-0.250000E-04	0.324900E-02	0.796281E+01	-0.311438E+05	-0.602530E+02
0.105000E-03	0.402100E-02	0.508383E+01	-0.131481E+05	-0.945279E+02
0.259000E-03	0.464800E-02	0.371525E+01	-0.462567E+04	-0.812167E+02
0.425000E-03	0.520100E-02	0.320541E+01	-0.151698E+04	-0.400704E+02
0.574000E-03	0.572400E-02	0.287323E+01	-0.239115E+04	-0.849206E+02
0.774000E-03	0.620000E-02	0.250782E+01	-0.169161E+04	-0.859573E+02
0.959000E-03	0.663500E-02	0.229895E+01	-0.566467E+03	-0.359498E+02
0.114600E-02	0.705500E-02	0.212494E+01	-0.129467E+04	-0.999536E+02
0.133900E-02	0.744100E-02	0.196939E+01	-0.317243E+03	-0.294418E+02
0.153400E-02	0.781900E-02	0.188574E+01	-0.540671E+03	-0.555972E+02
0.173100E-02	0.818000E-02	0.175780E+01	-0.758258E+03	-0.916758E+02
0.193200E-02	0.851800E-02	0.166915E+01	-0.123744E+03	-0.167974E+02
0.213300E-02	0.885100E-02	0.161543E+01	-0.410807E+03	-0.599029E+02
0.237000E-02	0.917200E-02	0.154294E+01	-0.299897E+03	-0.482470E+02
0.254200E-02	0.948200E-02	0.146319E+01	-0.478135E+03	-0.858947E+02
0.275000E-02	0.977600E-02	0.140865E+01	-0.462130E+02	-0.896394E+01
0.295800E-02	0.100680E-01	0.138140E+01	-0.215812E+03	-0.435133E+02
0.316700E-02	0.103520E-01	0.133122E+01	-0.264452E+03	-0.572962E+02
0.337800E-02	0.106270E-01	0.123764E+01	-0.622495E+03	-0.154527E+03
0.360600E-02	0.108930E-01	0.116447E+01	-0.192798E+02	-0.533138E+01
0.383400E-02	0.111580E-01	0.114693E+01	-0.134651E+03	-0.382172E+02
0.406200E-02	0.114160E-01	0.111586E+01	-0.137915E+03	-0.409966E+02
0.429200E-02	0.116590E-01	0.107387E+01	-0.227235E+03	-0.719204E+02
0.452300E-02	0.119110E-01	0.104762E+01	0.000000E+00	0.000000E+00
0.475400E-02	0.121530E-01	0.103461E+01	-0.112601E+03	-0.377968E+02
0.498600E-02	0.123900E-01	0.101080E+01	-0.927186E+02	-0.322542E+02
0.521900E-02	0.126230E-01	0.987124E+00	-0.110529E+03	-0.398400E+02
0.545200E-02	0.128500E-01	0.957247E+00	-0.145916E+03	-0.550048E+02
0.568600E-02	0.130700E-01	0.940173E+00	-0.177457E-01	-0.686274E-02
0.592000E-02	0.132900E-01	0.929681E+00	-0.896435E+02	-0.352162E+02

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0.615500E-02	0.135060E-01	0.910862E+00	-0.705231E+02	-0.284952E+02
0.639100E-02	0.137190E-01	0.895938E+00	-0.559693E+02	-0.231240E+02
0.662600E-02	0.139280E-01	0.881138E+00	-0.699834E+02	-0.295585E+02
0.686200E-02	0.141340E-01	0.856676E+00	-0.137328E+03	-0.601486E+02
0.710000E-02	0.143340E-01	0.842115E+00	0.149529E+02	0.669197E+01
0.733700E-02	0.145340E-01	0.837552E+00	-0.534272E+02	-0.240723E+02
0.757400E-02	0.147310E-01	0.823191E+00	-0.677892E+02	-0.311969E+02
0.781200E-02	0.149250E-01	0.810924E+00	-0.353171E+02	-0.165488E+02
0.805000E-02	0.151170E-01	0.800420E+00	-0.529589E+02	-0.252003E+02
0.828800E-02	0.153060E-01	0.784110E+00	-0.841189E+02	-0.409925E+02
0.852700E-02	0.154910E-01	0.771968E+00	-0.174711E+02	-0.866559E+01
0.876600E-02	0.156750E-01	0.765689E+00	-0.350091E+02	-0.175231E+02
0.900500E-02	0.158570E-01	0.757844E+00	-0.306526E+02	-0.155176E+02
0.924500E-02	0.160380E-01	0.749464E+00	-0.392261E+02	-0.340182E+02
0.948400E-02	0.162160E-01	0.736986E+00	-0.652113E+02	-0.200993E+02
0.972400E-02	0.163910E-01	0.721442E+00	-0.643356E+02	-0.343148E+02
0.996500E-02	0.165630E-01	0.713697E+00	0.000000E+00	0.000000E+00
0.102060E-01	0.167350E-01	0.711010E+00	-0.222952E+02	-0.120691E+02
0.104460E-01	0.169050E-01	0.704568E+00	-0.313528E+02	-0.171277E+02
0.128640E-01	0.185170E-01	0.637489E+00	-0.241342E+02	-0.144702E+02
0.152960E-01	0.199960E-01	0.586151E+00	-0.180845E+02	-0.116122E+02
0.177390E-01	0.213740E-01	0.548176E+00	-0.130042E+02	-0.876840E+01
0.201890E-01	0.226780E-01	0.519292E+00	-0.105740E+02	-0.739102E+01
0.226440E-01	0.239210E-01	0.495551E+00	-0.876802E+01	-0.630737E+01
0.251050E-01	0.251140E-01	0.475544E+00	-0.749115E+01	-0.551744E+01
0.275690E-01	0.262630E-01	0.457929E+00	-0.680649E+01	-0.511572E+01
0.300360E-01	0.273720E-01	0.441892E+00	-0.619603E+01	-0.474150E+01
0.325070E-01	0.284450E-01	0.427796E+00	-0.521306E+01	-0.405145E+01
0.349800E-01	0.294870E-01	0.415040E+00	-0.510315E+01	-0.402072E+01
0.374560E-01	0.304990E-01	0.402990E+00	-0.463139E+01	-0.370239E+01
0.399330E-01	0.314830E-01	0.391574E+00	-0.458578E+01	-0.369554E+01
0.424130E-01	0.324400E-01	0.380623E+00	-0.424539E+01	-0.346562E+01
0.448960E-01	0.333720E-01	0.370520E+00	-0.389264E+01	-0.320952E+01
0.473790E-01	0.342800E-01	0.361044E+00	-0.373947E+01	-0.311163E+01
0.498650E-01	0.351660E-01	0.351902E+00	-0.361544E+01	-0.303464E+01
0.523520E-01	0.360300E-01	0.343251E+00	-0.334198E+01	-0.282778E+01
0.548410E-01	0.368740E-01	0.335209E+00	-0.311949E+01	-0.265896E+01
0.573310E-01	0.376990E-01	0.327245E+00	-0.327682E+01	-0.281306E+01
0.598220E-01	0.385040E-01	0.319826E+00	-0.267945E+01	-0.231527E+01
0.623150E-01	0.392930E-01	0.313415E+00	-0.246342E+01	-0.214042E+01
0.648090E-01	0.400670E-01	0.307137E+00	-0.257216E+01	-0.224684E+01
0.673030E-01	0.408250E-01	0.300605E+00	-0.266605E+01	-0.234159E+01
0.697990E-01	0.415670E-01	0.294613E+00	-0.213376E+01	-0.188332E+01
0.722960E-01	0.422960E-01	0.289146E+00	-0.224557E+01	-0.199076E+01
0.747930E-01	0.430110E-01	0.283885E+00	-0.196820E+01	-0.175217E+01
0.772910E-01	0.437140E-01	0.279170E+00	-0.180816E+01	-0.161565E+01
0.797900E-01	0.444060E-01	0.274056E+00	-0.228450E+01	-0.204934E+01
0.822900E-01	0.450840E-01	0.269000E+00	-0.176020E+01	-0.158508E+01
0.847900E-01	0.457510E-01	0.264748E+00	-0.164233E+01	-0.148364E+01

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0.872910E+01	0.464080E-01	0.260444E+00	-0.179887E+01	-0.163022E+01
0.897930E-01	0.470540E-01	0.256196E+00	-0.159758E+01	-0.145227E+01
0.922950E-01	0.476900E-01	0.252148E+00	-0.163700E+01	-0.149244E+01
0.947980E-01	0.483160E-01	0.248302E+00	-0.143558E+01	-0.131236E+01
0.973010E-01	0.489330E-01	0.244618E+00	-0.150643E+01	-0.138067E+01
0.107319E+00	0.513080E-01	0.230299E+00	-0.135247E+01	-0.125159E+01
0.117345E+00	0.535490E-01	0.217234E+00	-0.125375E+01	-0.116997E+01
0.127376E+00	0.556650E-01	0.205156E+00	-0.115443E+01	-0.108521E+01
0.137413E+00	0.576660E-01	0.193946E+00	-0.107936E+01	-0.102120E+01
0.147454E+00	0.595590E-01	0.183355E+00	-0.103022E+01	-0.980366E+00
0.157500E+00	0.613490E-01	0.173362E+00	-0.959380E+00	-0.917699E+00
0.167551E+00	0.630430E-01	0.164098E+00	-0.884048E+00	-0.849504E+00
0.177604E+00	0.646480E-01	0.155198E+00	-0.886520E+00	-0.855428E+00
0.187661E+00	0.661640E-01	0.146700E+00	-0.803637E+00	-0.778375E+00
0.197720E+00	0.675990E-01	0.138563E+00	-0.814243E+00	-0.791343E+00
0.207782E+00	0.689520E-01	0.130578E+00	-0.772965E+00	-0.753608E+00
0.217846E+00	0.702270E-01	0.122946E+00	-0.743849E+00	-0.727296E+00
0.227913E+00	0.714270E-01	0.115466E+00	-0.742212E+00	-0.727612E+00
0.237982E+00	0.725520E-01	0.108099E+00	-0.721129E+00	-0.708671E+00
0.248052E+00	0.736040E-01	0.100984E+00	-0.692144E+00	-0.681690E+00
0.258124E+00	0.745860E-01	0.939648E-01	-0.701525E+00	-0.692335E+00
0.268198E+00	0.754970E-01	0.871054E-01	-0.660210E+00	-0.652767E+00
0.278272E+00	0.763410E-01	0.802983E-01	-0.691207E+00	-0.684576E+00
0.288348E+00	0.771150E-01	0.734881E-01	-0.660574E+00	-0.655259E+00
0.298425E+00	0.778220E-01	0.671302E-01	-0.601339E+00	-0.597297E+00
0.308503E+00	0.784680E-01	0.608226E-01	-0.650399E+00	-0.646807E+00
0.318582E+00	0.790480E-01	0.544203E-01	-0.620117E+00	-0.617372E+00
0.328661E+00	0.795650E-01	0.481675E-01	-0.620705E+00	-0.618551E+00
0.338741E+00	0.800190E-01	0.417143E-01	-0.659673E+00	-0.657955E+00
0.348822E+00	0.804060E-01	0.347687E-01	-0.718381E+00	-0.717080E+00
0.358903E+00	0.807200E-01	0.274278E-01	-0.737979E+00	-0.737147E+00
0.368984E+00	0.809590E-01	0.199388E-01	-0.747865E+00	-0.747419E+00
0.379065E+00	0.811220E-01	0.118044E-01	-0.866085E+00	-0.865904E+00
0.389147E+00	0.811970E-01	0.332186E-02	-0.816543E+00	-0.816530E+00
0.399229E+00	0.811890E-01	-0.530750E-02	-0.895341E+00	-0.895303E+00
0.409310E+00	0.810900E-01	-0.138879E-01	-0.806953E+00	-0.806720E+00
0.419391E+00	0.809090E-01	-0.221229E-01	-0.826853E+00	-0.826247E+00
0.429471E+00	0.806440E-01	-0.299602E-01	-0.728199E+00	-0.727220E+00
0.439551E+00	0.803050E-01	-0.373057E-01	-0.729322E+00	-0.727802E+00
0.449629E+00	0.798920E-01	-0.444039E-01	-0.679329E+00	-0.677324E+00
0.459707E+00	0.794100E-01	-0.510602E-01	-0.641629E+00	-0.639128E+00
0.469782E+00	0.788630E-01	-0.572704E-01	-0.591143E+00	-0.588247E+00
0.479857E+00	0.782560E-01	-0.631861E-01	-0.583323E+00	-0.579847E+00
0.489929E+00	0.775900E-01	-0.689085E-01	-0.552788E+00	-0.548874E+00
0.500000E+00	0.768680E-01	-0.745787E-01	-0.573440E+00	-0.568689E+00
0.510069E+00	0.760880E-01	-0.799610E-01	-0.495719E+00	-0.491003E+00
0.520135E+00	0.752580E-01	-0.850431E-01	-0.514051E+00	-0.508525E+00
0.530200E+00	0.743760E-01	-0.900242E-01	-0.475792E+00	-0.470066E+00
0.540263E+00	0.734460E-01	-0.949688E-01	-0.506492E+00	-0.499716E+00

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0.550323E+00	0.724650E-01	-0.998612E-01	-0.466609E+00	-0.459715E+00
0.560381E+00	0.714370E-01	-0.104262E+00	-0.408466E+00	-0.401895E+00
0.570436E+00	0.703680E-01	-0.108714E+00	-0.476986E+00	-0.468653E+00
0.580489E+00	0.692510E-01	-0.113118E+00	-0.399333E+00	-0.391789E+00
0.590539E+00	0.680940E-01	-0.117226E+00	-0.418097E+00	-0.409625E+00
0.600587E+00	0.668950E-01	-0.121243E+00	-0.381386E+00	-0.373128E+00
0.610631E+00	0.656580E-01	-0.125156E+00	-0.397758E+00	-0.388592E+00
0.620674E+00	0.643810E-01	-0.128972E+00	-0.362292E+00	-0.353437E+00
0.630713E+00	0.630680E-01	-0.132703E+00	-0.381149E+00	-0.371298E+00
0.640749E+00	0.617170E-01	-0.136280E+00	-0.331714E+00	-0.322683E+00
0.650782E+00	0.603330E-01	-0.139704E+00	-0.350585E+00	-0.340566E+00
0.660813E+00	0.589140E-01	-0.142986E+00	-0.303869E+00	-0.294782E+00
0.670840E+00	0.574650E-01	-0.146128E+00	-0.322789E+00	-0.312719E+00
0.680864E+00	0.559840E-01	-0.149364E+00	-0.322906E+00	-0.312394E+00
0.690885E+00	0.544710E-01	-0.152353E+00	-0.273543E+00	-0.264288E+00
0.700903E+00	0.529310E-01	-0.155302E+00	-0.315193E+00	-0.304124E+00
0.710917E+00	0.513600E-01	-0.158103E+00	-0.244137E+00	-0.235261E+00
0.720928E+00	0.497650E-01	-0.160648E+00	-0.264266E+00	-0.254356E+00
0.730936E+00	0.481440E-01	-0.163253E+00	-0.234838E+00	-0.225487E+00
0.740940E+00	0.448290E-01	-0.165709E+00	-0.243495E+00	-0.246295E+00
0.750941E+00	0.431410E-01	-0.167859E+00	-0.194959E+00	-0.187035E+00
0.760939E+00	0.414320E-01	-0.169918E+00	-0.217055E+00	-0.207983E+00
0.770933E+00	0.397040E-01	-0.171988E+00	-0.197098E+00	-0.188665E+00
0.780923E+00	0.379610E-01	-0.173741E+00	-0.153825E+00	-0.147114E+00
0.790911E+00	0.379610E-01	-0.175355E+00	-0.169275E+00	-0.161757E+00
0.800894E+00	0.362020E-01	-0.176878E+00	-0.135853E+00	-0.129718E+00
0.810874E+00	0.344300E-01	-0.178083E+00	-0.105657E+00	-0.100823E+00
0.820851E+00	0.326480E-01	-0.179098E+00	-0.977338E-01	-0.932131E-01
0.830824E+00	0.308570E-01	-0.180005E+00	-0.841168E-01	-0.801880E-01
0.840795E+00	0.290580E-01	-0.180770E+00	-0.693972E-01	-0.661294E-01
0.850761E+00	0.272530E-01	-0.181335E+00	-0.439997E-01	-0.419154E-01
0.860725E+00	0.254440E-01	-0.181741E+00	-0.375043E-01	-0.357200E-01
0.870685E+00	0.236320E-01	-0.182005E+00	-0.155597E-01	-0.148174E-01
0.880642E+00	0.218190E-01	-0.182101E+00	-0.371591E-02	-0.353846E-02
0.890597E+00	0.200060E-01	-0.182156E+00	-0.735266E-02	-0.698475E-02
0.900548E+00	0.181930E-01	-0.182010E+00	0.367684E-01	0.350141E-01
0.910497E+00	0.163840E-01	-0.181754E+00	0.146357E-01	0.139393E-01
0.920443E+00	0.145770E-01	-0.181347E+00	0.671530E-01	0.639714E-01
0.930387E+00	0.127770E-01	-0.180840E+00	0.349270E-01	0.332811E-01
0.940328E+00	0.109810E-01	-0.180415E+00	0.506000E-01	0.482263E-01
0.950269E+00	0.919000E-02	-0.179678E+00	0.976517E-01	0.931066E-01
0.960208E+00	0.740900E-02	-0.178982E+00	0.423161E-01	0.403612E-01
0.970148E+00	0.563200E-02	-0.178805E+00	-0.656194E-02	-0.625937E-02
0.980090E+00	0.385400E-02	-0.180442E+00	-0.322791E+00	-0.307644E+00
0.990038E+00	0.204300E-02	-0.193566E+00	-0.231577E+01	-0.219146E+01
0.999999E+00	0.000000E+00	-0.205100E+00	0.000000E+00	0.000000E+00

# PROFILE User's Guide (Appendix D, Sample 0)

Original lower surface

X	Y	Y'	Y''	CURVATURE
0.00000E+00	0.00000E+00	-0.343840E+01	0.00000E+00	0.00000E+00
0.62500E-03	-0.21490E-02	-0.260249E+01	0.267493E+04	0.123434E+03
0.10250E-02	-0.29760E-02	-0.191169E+01	0.779046E+03	0.775792E+02
0.13950E-02	-0.36300E-02	-0.162333E+01	0.779684E+03	0.112494E+03
0.17410E-02	-0.41450E-02	-0.140749E+01	0.467941E+03	0.909169E+02
0.20750E-02	-0.45890E-02	-0.129782E+01	0.188775E+03	0.429231E+02
0.24050E-02	-0.50070E-02	-0.121676E+01	0.302439E+03	0.774148E+02
0.27260E-02	-0.53820E-02	-0.111536E+01	0.329351E+03	0.979747E+02
0.30410E-02	-0.57170E-02	-0.104607E+01	0.110625E+03	0.365012E+02
0.33540E-02	-0.60390E-02	-0.984639E+00	0.281895E+03	0.101988E+03
0.36610E-02	-0.63280E-02	-0.936241E+00	0.334010E+02	0.129933E+02
0.39660E-02	-0.66120E-02	-0.907740E+00	0.153497E+03	0.623111E+02
0.42690E-02	-0.68800E-02	-0.853411E+00	0.205122E+03	0.902777E+02
0.45680E-02	-0.71260E-02	-0.816054E+00	0.447332E+02	0.208036E+02
0.48670E-02	-0.73680E-02	-0.796509E+00	0.859928E+02	0.411542E+02
0.51630E-02	-0.76000E-02	-0.768138E+00	0.105716E+03	0.527268E+02
0.54580E-02	-0.78220E-02	-0.730610E+00	0.148689E+03	0.782761E+02
0.57500E-02	-0.80290E-02	-0.705480E+00	0.234433E+02	0.127903E+02
0.60420E-02	-0.82340E-02	-0.691216E+00	0.742449E+02	0.413287E+02
0.63330E-02	-0.84320E-02	-0.670624E+00	0.672833E+02	0.385455E+02
0.66230E-02	-0.86230E-02	-0.665134E+00	0.292963E+02	-0.169115E+02
0.68940E-02	-0.88050E-02	-0.669118E+00	0.112988E-01	0.648645E-02
0.71660E-02	-0.89870E-02	-0.658087E+00	0.811030E+02	0.472751E+02
0.74380E-02	-0.91630E-02	-0.640171E+00	0.506449E+02	0.302546E+02
0.77080E-02	-0.93340E-02	-0.615891E+00	0.129219E+03	0.797676E+02
0.79770E-02	-0.94950E-02	-0.600371E+00	-0.138187E+02	-0.870856E+01
0.82460E-02	-0.96570E-02	-0.594010E+00	0.611289E+02	0.388484E+02
0.85140E-02	-0.98140E-02	-0.579417E+00	0.478000E+02	0.309637E+02
0.87810E-02	-0.99670E-02	-0.567416E+00	0.421081E+02	0.277037E+02
0.90480E-02	-0.101170E-01	-0.545909E+00	0.119013E+03	0.804772E+02
0.93140E-02	-0.102580E-01	-0.531955E+00	-0.141103E+02	-0.970978E+01
0.95800E-02	-0.10400E-01	-0.531062E+00	0.208237E+02	0.143454E+02
0.98450E-02	-0.105400E-01	-0.508530E+00	0.497278E+02	0.346555E+02
0.101090E-01	-0.106760E-01	-0.499044E+00	0.501453E+02	0.355138E+02
0.103740E-01	-0.108090E-01	-0.484706E+00	0.214417E+02	0.153600E+02
0.106380E-01	-0.109400E-01	-0.476182E+00	0.871814E+02	0.635265E+02
0.109000E-01	-0.110640E-01	-0.473382E+00	-0.220865E+02	-0.162552E+02
0.111630E-01	-0.111900E-01	-0.464749E+00	0.433713E+02	0.320245E+02
0.114280E-01	-0.113130E-01	-0.456110E+00	0.222750E+02	0.166120E+02
0.116880E-01	-0.114340E-01	-0.446563E+00	0.437054E+02	0.329166E+02
0.119500E-01	-0.115520E-01	-0.435921E+00	0.291285E+02	0.221749E+02
0.122120E-01	-0.116680E-01	-0.429122E+00	0.521073E+02	0.401387E+02
0.124730E-01	-0.117800E-01	-0.427200E+00	0.127885E-01	0.992457E-02
0.127340E-01	-0.118920E-01	-0.422253E+00	0.146812E+02	0.114172E+02
0.129950E-01	-0.120030E-01	-0.422253E+00	0.232550E+02	0.181816E+02

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0.132550E-01	-0.121120E-01	-0.414608E+00	0.355901E+02	0.280539E+02
0.135160E-01	-0.122190E-01	-0.406897E+00	0.234738E+02	0.186543E+02
0.137760E-01	-0.123240E-01	-0.396893E+00	0.535036E+02	0.429623E+02
0.140350E-01	-0.124250E-01	-0.391892E+00	-0.149191E+02	-0.120413E+02
0.142940E-01	-0.125270E-01	-0.389225E+00	0.354954E+02	0.287262E+02
0.145540E-01	-0.126270E-01	-0.382449E+00	0.166483E+02	0.135657E+02
0.147130E-01	-0.127270E-01	-0.341252E+00	0.152655E+02	0.129405E+02
0.149740E-01	-0.128270E-01	-0.307060E+00	0.113641E+02	0.992746E+01
0.152350E-01	-0.129270E-01	-0.282330E+00	0.797878E+01	0.711174E+01
0.154960E-01	-0.130270E-01	-0.264165E+00	0.626829E+01	0.566507E+01
0.157570E-01	-0.131270E-01	-0.249591E+00	0.518484E+01	0.473552E+01
0.160180E-01	-0.132270E-01	-0.237629E+00	0.423767E+01	0.390250E+01
0.162790E-01	-0.133270E-01	-0.227257E+00	0.394124E+01	0.365451E+01
0.165400E-01	-0.134270E-01	-0.217694E+00	0.361027E+01	0.336803E+01
0.168010E-01	-0.135270E-01	-0.209253E+00	0.306402E+01	0.287325E+01
0.170620E-01	-0.136270E-01	-0.201936E+00	0.272736E+01	0.256865E+01
0.173230E-01	-0.137270E-01	-0.194966E+00	0.279587E+01	0.264371E+01
0.175840E-01	-0.138270E-01	-0.188377E+00	0.242742E+01	0.230372E+01
0.178450E-01	-0.139270E-01	-0.182049E+00	0.259461E+01	0.247077E+01
0.181060E-01	-0.140270E-01	-0.175804E+00	0.236769E+01	0.226201E+01
0.183670E-01	-0.141270E-01	-0.169088E+00	0.197356E+01	0.189067E+01
0.186280E-01	-0.142270E-01	-0.159632E+00	0.234827E+01	0.225563E+01
0.188890E-01	-0.143270E-01	-0.154948E+00	0.185123E+01	0.178265E+01
0.191500E-01	-0.144270E-01	-0.150428E+00	0.187915E+01	0.181345E+01
0.194110E-01	-0.145270E-01	-0.146131E+00	0.172302E+01	0.166615E+01
0.196720E-01	-0.146270E-01	-0.142230E+00	0.170259E+01	0.164948E+01
0.199330E-01	-0.147270E-01	-0.138667E+00	0.140947E+01	0.136776E+01
0.201940E-01	-0.148270E-01	-0.135328E+00	0.123172E+01	0.139329E+01
0.204550E-01	-0.149270E-01	-0.132015E+00	0.123172E+01	0.119865E+01
0.207160E-01	-0.150270E-01	-0.128446E+00	0.141478E+01	0.137859E+01
0.209770E-01	-0.151270E-01	-0.125674E+00	0.143651E+01	0.140168E+01
0.212380E-01	-0.152270E-01	-0.123525E+00	0.777646E+00	0.759580E+00
0.214990E-01	-0.153270E-01	-0.120575E+00	0.939407E+00	0.918309E+00
0.217600E-01	-0.154270E-01	-0.117824E+00	0.141941E+01	0.138901E+01
0.220210E-01	-0.155270E-01	-0.115646E+00	0.781850E+00	0.765847E+00
0.222820E-01	-0.156270E-01	-0.113245E+00	0.960415E+00	0.941465E+00
0.225430E-01	-0.157270E-01	-0.111066E+00	0.961348E+00	0.943146E+00
0.228040E-01	-0.158270E-01	-0.109108E+00	0.782321E+00	0.768066E+00
0.230650E-01	-0.159270E-01	-0.107129E+00	0.784194E+00	0.770396E+00
0.233260E-01	-0.160270E-01	-0.105158E+00	0.801492E+00	0.787890E+00
0.235870E-01	-0.161270E-01	-0.103189E+00	0.776441E+00	0.763738E+00
0.238480E-01	-0.162270E-01	-0.101220E+00	0.695212E+00	0.685353E+00
0.241090E-01	-0.163270E-01	-0.978125E-01	0.639098E+00	0.631213E+00
0.243700E-01	-0.164270E-01	-0.911582E-01	0.588906E+00	0.582576E+00
0.246310E-01	-0.165270E-01	-0.850374E-01	0.551130E+00	0.545964E+00
0.248920E-01	-0.166270E-01	-0.793585E-01	0.520170E+00	0.515924E+00
0.251530E-01	-0.167270E-01	-0.740241E-01	0.502744E+00	0.499182E+00
0.254140E-01	-0.168270E-01	-0.689335E-01	0.432525E+00	0.429858E+00
0.256750E-01	-0.169270E-01	-0.642803E-01	0.462718E+00	0.460245E+00
0.259360E-01	-0.170270E-01	-0.598280E-01		
0.261970E-01	-0.171270E-01			
0.264580E-01	-0.172270E-01			
0.267190E-01	-0.173270E-01			
0.269800E-01	-0.174270E-01			
0.272410E-01	-0.175270E-01			
0.275020E-01	-0.176270E-01			
0.277630E-01	-0.177270E-01			
0.280240E-01	-0.178270E-01			
0.282850E-01	-0.179270E-01			
0.285460E-01	-0.180270E-01			
0.288070E-01	-0.181270E-01			
0.290680E-01	-0.182270E-01			
0.293290E-01	-0.183270E-01			
0.295900E-01	-0.184270E-01			
0.298510E-01	-0.185270E-01			
0.301120E-01	-0.186270E-01			
0.303730E-01	-0.187270E-01			
0.306340E-01	-0.188270E-01			
0.308950E-01	-0.189270E-01			
0.311560E-01	-0.190270E-01			
0.314170E-01	-0.191270E-01			
0.316780E-01	-0.192270E-01			
0.319390E-01	-0.193270E-01			
0.322000E-01	-0.194270E-01			
0.324610E-01	-0.195270E-01			
0.327220E-01	-0.196270E-01			
0.329830E-01	-0.197270E-01			
0.332440E-01	-0.198270E-01			
0.335050E-01	-0.199270E-01			
0.337660E-01	-0.200270E-01			
0.340270E-01	-0.201270E-01			
0.342880E-01	-0.202270E-01			
0.345490E-01	-0.203270E-01			
0.348100E-01	-0.204270E-01			
0.350710E-01	-0.205270E-01			
0.353320E-01	-0.206270E-01			
0.355930E-01	-0.207270E-01			
0.358540E-01	-0.208270E-01			
0.361150E-01	-0.209270E-01			
0.363760E-01	-0.210270E-01			
0.366370E-01	-0.211270E-01			
0.368980E-01	-0.212270E-01			
0.371590E-01	-0.213270E-01			
0.374200E-01	-0.214270E-01			
0.376810E-01	-0.215270E-01			
0.379420E-01	-0.216270E-01			
0.382030E-01	-0.217270E-01			
0.384640E-01	-0.218270E-01			
0.387250E-01	-0.219270E-01			
0.389860E-01	-0.220270E-01			
0.392470E-01	-0.221270E-01			
0.395080E-01	-0.222270E-01			
0.397690E-01	-0.223270E-01			
0.400300E-01	-0.224270E-01			
0.402910E-01	-0.225270E-01			
0.405520E-01	-0.226270E-01			
0.408130E-01	-0.227270E-01			
0.410740E-01	-0.228270E-01			
0.413350E-01	-0.229270E-01			
0.415960E-01	-0.230270E-01			
0.418570E-01	-0.231270E-01			
0.421180E-01	-0.232270E-01			
0.423790E-01	-0.233270E-01			
0.426400E-01	-0.234270E-01			
0.429010E-01	-0.235270E-01			
0.431620E-01	-0.236270E-01			
0.434230E-01	-0.237270E-01			
0.436840E-01	-0.238270E-01			
0.439450E-01	-0.239270E-01			
0.442060E-01	-0.240270E-01			
0.444670E-01	-0.241270E-01			
0.447280E-01	-0.242270E-01			
0.449890E-01	-0.243270E-01			
0.452500E-01	-0.244270E-01			
0.455110E-01	-0.245270E-01			
0.457720E-01	-0.246270E-01			
0.460330E-01	-0.247270E-01			
0.462940E-01	-0.248270E-01			
0.465550E-01	-0.249270E-01			
0.468160E-01	-0.250270E-01			
0.470770E-01	-0.251270E-01			
0.473380E-01	-0.252270E-01			
0.475990E-01	-0.253270E-01			
0.478600E-01	-0.254270E-01			
0.481210E-01	-0.255270E-01			
0.483820E-01	-0.256270E-01			
0.486430E-01	-0.257270E-01			
0.489040E-01	-0.258270E-01			
0.491650E-01	-0.259270E-01			
0.494260E-01	-0.260270E-01			
0.496870E-01	-0.261270E-01			
0.499480E-01	-0.262270E-01			
0.502090E-01	-0.263270E-01			
0.504700E-01	-0.264270E-01			
0.507310E-01	-0.265270E-01			
0.509920E-01	-0.266270E-01			
0.512530E-01	-0.267270E-01			
0.515140E-01	-0.268270E-01			
0.517750E-01	-0.269270E-01			
0.520360E-01	-0.270270E-01			
0.522970E-01	-0.271270E-01			
0.525580E-01	-0.272270E-01			
0.528190E-01	-0.273270E-01			
0.530800E-01	-0.274270E-01			
0.533410E-01	-0.275270E-01			
0.536020E-01	-0.276270E-01			
0.538630E-01	-0.277270E-01			
0.541240E-01	-0.278270E-01			
0.543850E-01	-0.279270E-01			
0.546460E-01	-0.280270E-01			
0.549070E-01	-0.281270E-01			
0.551680E-01	-0.282270E-01			
0.554290E-01	-0.283270E-01			
0.556900E-01	-0.284270E-01			
0.559510E-01	-0.285270E-01			
0.562120E-01	-0.286270E-01			
0.564730E-01	-0.287270E-01			
0.567340E-01	-0.288270E-01			
0.569950E-01	-0.289270E-01			
0.572560E-01	-0.290270E-01			
0.575170E-01	-0.291270E-01			
0.577780E-01	-0.292270E-01			
0.580390E-01	-0.293270E-01			
0.583000E-01	-0.294270E-01			
0.585610E-01	-0.295270E-01			
0.588220E-01	-0.296270E-01			
0.590830E-01	-0.297270E-01			
0.593440E-01	-0.298270E-01			
0.596050E-01	-0.299270E-01			
0.598660E-01	-0.300270E-01			
0.601270E-01	-0.301270E-01			
0.603880E-01	-0.302270E-01			
0.606490E-01	-0.303270E-01			
0.609100E-01	-0.304270E-01			
0.611710E-01	-0.305270E-01			
0.614320E-01	-0.306270E-01			
0.616930E-01	-0.307270E-01			
0.619540E-01	-0.308270E-01			
0.622150E-01	-0.309270E-01			
0.624760E-01	-0.310270E-01			
0.627370E-01	-0.311270E-01			
0.629980E-01	-0.312270E-01			
0.632590E-01	-0.313270E-01			
0.635200E-01	-0.314270E-01			
0.637810E-01	-0.315270E-01			
0.640420E-01	-0.316270E-01			
0.643030E-01	-0.317270E-01			
0.645640E-01	-0.318270E-01			
0.648250E-01	-0.319270E-01			
0.650860E-01	-0.320270E-01			
0.653470E-01	-0.321270E-01			
0.656080E-01	-0.322270E-01			
0.658690E-01	-0.323270E-01			
0.661300E-01	-			



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0.192339E+00	-0.352100E-01	-0.555217E-01	0.403550E+00	0.401691E+00
0.202280E+00	-0.357420E-01	-0.514105E-01	0.423594E+00	0.421920E+00
0.212218E+00	-0.362320E-01	-0.473478E-01	0.393985E+00	0.392664E+00
0.222154E+00	-0.366830E-01	-0.434844E-01	0.383686E+00	0.382601E+00
0.232087E+00	-0.370960E-01	-0.395686E-01	0.404711E+00	0.403763E+00
0.242018E+00	-0.374690E-01	-0.356979E-01	0.374848E+00	0.374133E+00
0.251948E+00	-0.378050E-01	-0.319767E-01	0.374632E+00	0.374058E+00
0.261876E+00	-0.381040E-01	-0.282055E-01	0.385092E+00	0.384632E+00
0.271802E+00	-0.383650E-01	-0.245817E-01	0.345062E+00	0.344750E+00
0.281728E+00	-0.385920E-01	-0.209567E-01	0.385356E+00	0.385102E+00
0.291652E+00	-0.387810E-01	-0.172324E-01	0.365274E+00	0.365111E+00
0.301574E+00	-0.389340E-01	-0.138075E-01	0.325199E+00	0.325107E+00
0.311497E+00	-0.390550E-01	-0.104310E-01	0.355283E+00	0.355225E+00
0.321418E+00	-0.391410E-01	-0.690456E-02	0.355564E+00	0.355539E+00
0.331338E+00	-0.391920E-01	-0.347765E-02	0.335352E+00	0.335346E+00
0.341259E+00	-0.392100E-01	0.201941E-03	0.406479E+00	0.406479E+00
0.351178E+00	-0.391880E-01	0.443565E-02	0.447250E+00	0.447237E+00
0.361097E+00	-0.391220E-01	0.902321E-02	0.477699E+00	0.477641E+00
0.371016E+00	-0.390900E-01	0.139125E-01	0.508208E+00	0.508060E+00
0.380935E+00	-0.388460E-01	0.194588E-01	0.610116E+00	0.609769E+00
0.390853E+00	-0.386230E-01	0.253579E-01	0.579482E+00	0.578924E+00
0.400771E+00	-0.383430E-01	0.314057E-01	0.640119E+00	0.639173E+00
0.410690E+00	-0.380000E-01	0.374535E+00	0.579305E+00	0.578088E+00
0.420609E+00	-0.376000E-01	0.432501E-01	0.589504E+00	0.587854E+00
0.430528E+00	-0.371420E-01	0.484873E-01	0.466554E+00	0.464913E+00
0.440449E+00	-0.366380E-01	0.533214E-01	0.507931E+00	0.505772E+00
0.450370E+00	-0.360840E-01	0.580523E-01	0.445773E+00	0.443529E+00
0.460293E+00	-0.354860E-01	0.621754E-01	0.385263E+00	0.383040E+00
0.470217E+00	-0.348500E-01	0.657930E-01	0.343797E+00	0.341577E+00
0.480143E+00	-0.341800E-01	0.692553E-01	0.353764E+00	0.351234E+00
0.490071E+00	-0.334750E-01	0.724681E-01	0.293476E+00	0.291180E+00
0.500000E+00	-0.327410E-01	0.755787E-01	0.333112E+00	0.330278E+00
0.509931E+00	-0.319740E-01	0.784833E-01	0.251844E+00	0.249535E+00
0.519864E+00	-0.311820E-01	0.810304E-01	0.261066E+00	0.258516E+00
0.529800E+00	-0.303640E-01	0.835305E-01	0.242189E+00	0.239677E+00
0.539737E+00	-0.295220E-01	0.859280E-01	0.240351E+00	0.237714E+00
0.549677E+00	-0.286560E-01	0.881196E-01	0.200621E+00	0.198306E+00
0.559619E+00	-0.277700E-01	0.899581E-01	0.169240E+00	0.167206E+00
0.569564E+00	-0.268670E-01	0.918961E-01	0.220553E+00	0.217788E+00
0.579511E+00	-0.259420E-01	0.936367E-01	0.129425E+00	0.127741E+00
0.589460E+00	-0.250040E-01	0.951157E-01	0.167853E+00	0.165600E+00
0.599413E+00	-0.240490E-01	0.964435E-01	0.988999E-01	0.975359E-01
0.609368E+00	-0.230840E-01	0.976244E-01	0.138323E+00	0.136369E+00
0.619326E+00	-0.221050E-01	0.987498E-01	0.877184E-01	0.864508E-01
0.629287E+00	-0.211170E-01	0.996787E-01	0.987652E-01	0.973113E-01
0.639250E+00	-0.201190E-01	0.100451E+00	0.563231E-01	0.554813E-01
0.649217E+00	-0.191150E-01	0.101018E+00	0.573212E-01	0.564549E-01
0.659187E+00	-0.181050E-01	0.101494E+00	0.382542E-01	0.376707E-01
0.669159E+00	-0.170910E-01	0.101714E+00	0.591040E-02	0.581985E-02

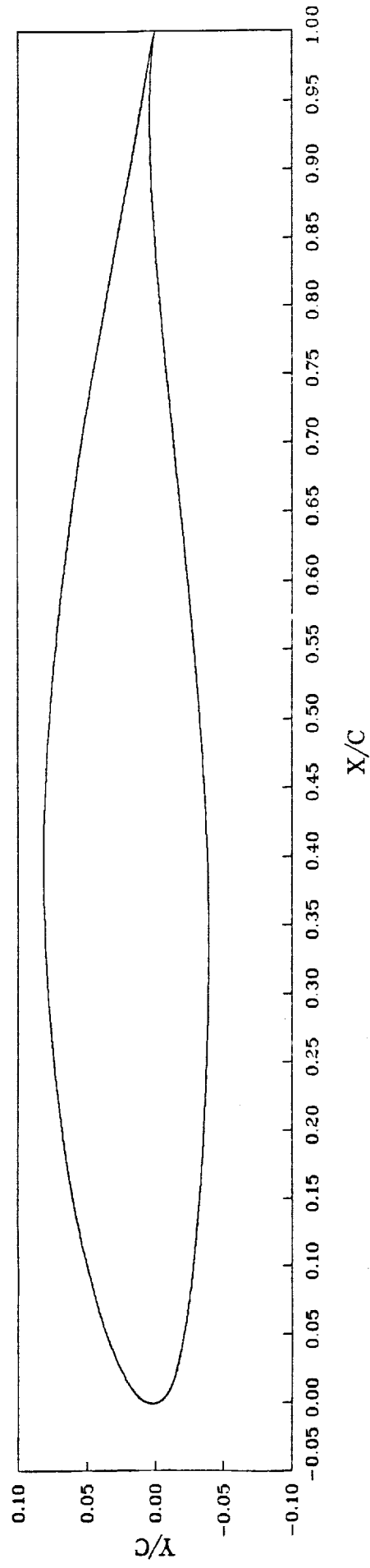
# PROFILE User's Guide (Appendix D, Sample 0)

0.679135E+00	-0.160760E-01	0.101879E+00	0.271476E-01	0.267304E-01
0.689114E+00	-0.150580E-01	0.101894E+00	-0.242214E-01	-0.238490E-01
0.699097E+00	-0.140420E-01	0.101763E+00	-0.204707E-02	-0.201568E-02
0.709082E+00	-0.130260E-01	0.101382E+00	-0.741763E-01	-0.730472E-01
0.719071E+00	-0.120170E-01	0.100796E+00	-0.431531E-01	-0.425037E-01
0.729063E+00	-0.110120E-01	0.100110E+00	-0.941019E-01	-0.927048E-01
0.739059E+00	-0.100160E-01	0.991748E-01	-0.930706E-01	-0.917142E-01
0.749058E+00	-0.902900E-02	0.978950E-01	-0.162905E+00	-0.160591E+00
0.759060E+00	-0.805800E-02	0.964118E-01	-0.133674E+00	-0.131832E+00
0.769066E+00	-0.710000E-02	0.948247E-01	-0.183562E+00	-0.181114E+00
0.779076E+00	-0.616000E-02	0.928433E-01	-0.212334E+00	-0.209618E+00
0.789089E+00	-0.524100E-02	0.906189E-01	-0.231962E+00	-0.229134E+00
0.799105E+00	-0.434500E-02	0.880921E-01	-0.272593E+00	-0.269451E+00
0.809125E+00	-0.347600E-02	0.851673E-01	-0.311198E+00	-0.307842E+00
0.819148E+00	-0.263800E-02	0.818960E-01	-0.341558E+00	-0.338150E+00
0.829175E+00	-0.183400E-02	0.782812E-01	-0.379459E+00	-0.375998E+00
0.839204E+00	-0.106800E-02	0.743668E-01	-0.401148E+00	-0.397844E+00
0.849238E+00	-0.342000E-03	0.700054E-01	-0.468176E+00	-0.464755E+00
0.859274E+00	0.337000E-03	0.651533E-01	-0.498763E+00	-0.495604E+00
0.869314E+00	0.966000E-03	0.599547E-01	-0.536806E+00	-0.533925E+00
0.879356E+00	0.154100E-02	0.541630E-01	-0.616696E+00	-0.613992E+00
0.889402E+00	0.205400E-02	0.478239E-01	-0.645337E+00	-0.643130E+00
0.899451E+00	0.250200E-02	0.409459E-01	-0.723547E+00	-0.721731E+00
0.909502E+00	0.287700E-02	0.332268E-01	-0.812441E+00	-0.811097E+00
0.919556E+00	0.317000E-02	0.245161E-01	-0.920331E+00	-0.919502E+00
0.929612E+00	0.337000E-02	0.148166E-01	-0.100878E+01	-0.100844E+01
0.939670E+00	0.346800E-02	0.387823E-02	-0.116628E+01	-0.116625E+01
0.949730E+00	0.344800E-02	-0.919361E-02	-0.143251E+01	-0.143233E+01
0.959791E+00	0.328300E-02	-0.249499E-01	-0.169962E+01	-0.169803E+01
0.969851E+00	0.294600E-02	-0.444898E-01	-0.218504E+01	-0.217857E+01
0.979909E+00	0.238800E-02	-0.708196E-01	-0.305057E+01	-0.302776E+01
0.989961E+00	0.152200E-02	-0.118911E+00	-0.651794E+01	-0.638210E+01
0.999999E+00	0.000000E+00	-0.151624E+00	0.000000E+00	0.000000E+00

Original X thickness: 12.00033  
Corresponding abscissa: 0.3790650

NACA 64412 airfoil  
Example 1 MODE 0

NACA 64412



# PROFILE User's Guide (Appendix D, Sample 1)

## (1) NACA 6-Series Airfoil - Mode 1 (rectify leading edge)

The leading edge of the NACA 6-series airfoil used here is not the most forward point on the airfoil. Note the negative abscissas on the upper surface in the set of tabulated coordinates for example 1. To avoid problems with spline fitting, estimating derivatives, and applying shape functions, the leading edge definition needs to be "rectified" so that both surfaces are monotonic.

### Sample Terminal Session - Rectify leading edge definition

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:

- 0 = default (no modifications) - just plot and tabulate
- 1 = rectify leading edge definition
- 2 = normalize or de-normalize geometry
- 3 = redistribute the abscissas
- 4 = modify - apply shape functions
- 5 = refine thickness/curvature
- 6 = optimize one surface (bumps + target curvatures)

Enter MODE, else <CR> for MODE = 0: 1

Enter the PROFILE control file (default is PROFILE.INP):

NACA64412.INP

Enter the airfoil geometry data file (default is AIRFOIL.DAT):

NACA64412.DAT

Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.\*:

RECT64412

Enter plot title (up to 80 chars.) <CR> uses PROFILE for the title:

NACA airfoil with rectified leading edge

Enter plot subtitle (up to 80 characters) or <CR> if none:

Example 2 MODE 1

Original % thickness: 12.00033 Corresponding X: 0.3790650

Modified airfoil: RECT64412.DAT

Airfoil plot file: RECT64412.PLT

Tabulated results: RECT64412.TAB

Curvature QPLOT file: RECT64412.CRV

2nd derivatives file: RECT64412.YPP

RECT64412.TAB file (abbreviated)

Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

# PROFILE User's Guide (Appendix D, Sample 1)

Operating mode: 1  
Control file : NACA64412.INP  
Geometry file : NACA64412.DAT  
Output file id: RECT64412  
Profiles found: 1

NACA 64412 airfoil with rectified leading edge  
Revised upper surface

X	Y	Y'	Y''	CURVATURE
-0.125000E-03	0.229700E-02	0.952000E+01	0.000000E+00	0.000000E+00
-0.250000E-04	0.324900E-02	0.796281E+01	-0.311438E+05	-0.602530E+02
0.105000E-03	0.402100E-02	0.508383E+01	-0.131481E+05	-0.945279E+02
0.259000E-03	0.464800E-02	0.371525E+01	-0.462567E+04	-0.812167E+02
0.425000E-03	0.520100E-02	0.320541E+01	-0.151698E+04	-0.400704E+02
0.595000E-03	0.572400E-02	0.287323E+01	-0.239115E+04	-0.849206E+02
0.774000E-03	0.620000E-02	0.250782E+01	-0.169161E+04	-0.859573E+02
0.940328E+00	0.109810E-01	-0.180415E+00	0.506000E-01	0.482263E-01
0.950269E+00	0.919000E-02	-0.179678E+00	0.976517E-01	0.931066E-01
0.960208E+00	0.740900E-02	-0.178982E+00	0.423161E-01	0.403612E-01
0.970114E+00	0.563200E-02	-0.178805E+00	-0.656194E-02	-0.625937E-02
0.980090E+00	0.385400E-02	-0.180442E+00	-0.322791E+00	-0.307644E+00
0.990038E+00	0.204300E-02	-0.193566E+00	-0.231577E+01	-0.219146E+01
0.999999E+00	0.000000E+00	-0.205100E+00	0.000000E+00	0.000000E+00

NACA 64412 airfoil with rectified leading edge  
Revised lower surface

X	Y	Y'	Y''	CURVATURE
-0.125000E-03	0.229700E-02	-0.183760E+02	0.000000E+00	0.000000E+00
0.000000E+00	0.000000E+00	-0.158864E+02	0.398336E+05	0.987636E+01
0.625000E-03	-0.214900E-02	-0.260249E+01	0.267493E+04	0.123434E+03
0.102500E-02	-0.297600E-02	-0.191169E+01	0.779004E+03	0.775792E+02
0.139500E-02	-0.363000E-02	-0.162333E+01	0.779684E+03	0.112494E+03
0.174100E-02	-0.414500E-02	-0.140749E+01	0.467941E+03	0.909169E+02
0.207500E-02	-0.458900E-02	-0.129782E+01	0.188775E+03	0.429231E+02
0.939670E+00	0.346800E-02	0.387823E-02	-0.116628E+01	-0.116625E+01
0.949730E+00	0.344800E-02	-0.919361E-02	-0.143251E+01	-0.143233E+01
0.959791E+00	0.328300E-02	-0.249499E-01	-0.169962E+01	-0.169803E+01

PROFILE User's Guide (Appendix D, Sample 1)

0.969851E+00	0.294600E-02	-0.444898E-01	-0.218504E+01	-0.217857E+01
0.979909E+00	0.238800E-02	-0.708196E-01	-0.305057E+01	-0.302776E+01
0.989961E+00	0.152200E-02	-0.118911E+00	-0.651794E+01	-0.638210E+01
0.999999E+00	0.000000E+00	-0.151624E+00	0.000000E+00	0.000000E+00

Current % thickness: 12.00033  
 Corresponding abscissa: 0.3790650

# PROFILE User's Guide (Appendix D, Sample 2)

## (2) NACA 6-Series Airfoil - Mode 2 (normalize/denormalize)

A normalized airfoil geometry input data set is assumed when running with MODE=3 or greater. The NACA 6-series airfoil of the previous example is normalized here.

### Sample Terminal Session - Normalize geometry

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:

- 0 = default (no modifications) - just plot and tabulate
- 1 = rectify leading edge definition
- 2 = normalize or de-normalize geometry
- 3 = redistribute the abscissas
- 4 = modify - apply shape functions
- 5 = refine thickness/curvature
- 6 = optimize one surface (bumps + target curvatures)

Enter MODE, else <CR> for MODE = 0: 2

Enter the PROFILE control file (default is PROFILE.INP):

NACA64412.INP

Enter the airfoil geometry data file (default is AIRFOIL.DAT):

RECT64412.DAT

Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.\*:

NORM64412

Enter plot title (up to 80 chars.) <CR> uses PROFILE for the title:

Normalized NACA 64412 airfoil with rectified leading edge

Enter plot subtitle (up to 80 characters) or <CR> if none:

Example 2 MODE 2

The chord of your original profile is: 1.000124

Enter <CR> to normalize by this chord, or enter a

different chord: (a negative value de-normalizes): <CR>

Original % thickness: 11.99883

Corresponding X: 0.3790650

Current % thickness: 11.99883

Corresponding X: 0.3791430

Modified airfoil:

NORM64412.DAT

Airfoil plot file:

NORM64412.PLT

Tabulated results:

NORM64412.TAB

Curvature QPLOT file:

NORM64412.CRV

2nd derivatives file: NORM64412.YPP

NORM64412.TAB file (abbreviated)

# PROFILE User's Guide (Appendix D, Sample 2)

## Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

Operating mode: 2  
Control file : NACA64412.INP  
Geometry file : RECT64412.DAT  
Output file id: NORM64412  
Profiles found: 1

### NACA 64412 airfoil with rectified leading edge Original upper surface

X	Y	Y'	Y''	CURVATURE
-0.125000E-03	0.229700E-02	0.952000E+01	0.000000E+00	0.000000E+00
-0.250000E-04	0.324900E-02	0.796281E+01	-0.311438E+05	-0.602530E+02
0.105000E-03	0.402100E-02	0.508383E+01	-0.131481E+05	-0.945279E+02
0.259000E-03	0.464800E-02	0.371525E+01	-0.462567E+04	-0.812167E+02
0.425000E-03	0.520100E-02	0.320541E+01	-0.151698E+04	-0.400704E+02
0.595000E-03	0.572400E-02	0.287323E+01	-0.239115E+04	-0.849206E+02
0.774000E-03	0.620000E-02	0.250782E+01	-0.169161E+04	-0.859573E+02
0.940328E+00	0.109810E-01	-0.180415E+00	0.506000E-01	0.482263E-01
0.950269E+00	0.919000E-02	-0.179678E+00	0.976517E-01	0.931066E-01
0.960208E+00	0.740900E-02	-0.178982E+00	0.423161E-01	0.403612E-01
0.970148E+00	0.563200E-02	-0.178805E+00	-0.656194E-02	-0.625937E-02
0.980090E+00	0.385400E-02	-0.180442E+00	-0.322791E+00	-0.307644E+00
0.990038E+00	0.204300E-02	-0.193566E+00	-0.231577E+01	-0.219146E+01
0.999999E+00	0.000000E+00	-0.205100E+00	0.000000E+00	0.000000E+00

### NACA 64412 airfoil with rectified leading edge Original lower surface

X	Y	Y'	Y''	CURVATURE
-0.125000E-03	0.229700E-02	-0.183760E+02	0.000000E+00	0.000000E+00
0.000000E+00	0.000000E+00	-0.158864E+02	0.398336E+05	0.987636E+01
0.625000E-03	-0.214900E-02	-0.260249E+01	0.267493E+04	0.123434E+03
0.102500E-02	-0.297600E-02	-0.191169E+01	0.779046E+03	0.775792E+02
0.139500E-02	-0.363000E-02	-0.162333E+01	0.779684E+03	0.112494E+03
0.174100E-02	-0.414500E-02	-0.140749E+01	0.467941E+03	0.909169E+02
0.207500E-02	-0.458900E-02	-0.129782E+01	0.188775E+03	0.429231E+02
0.939670E+00	0.346800E-02	0.387823E-02	-0.116628E+01	-0.116625E+01



# PROFILE User's Guide (Appendix D, Sample 2)

0.949730E+00	0.344800E-02	-0.919361E-02	-0.143251E+01	-0.143233E+01
0.959791E+00	0.328300E-02	-0.249499E-01	-0.169962E+01	-0.169803E+01
0.969851E+00	0.294600E-02	-0.444898E-01	-0.218504E+01	-0.217857E+01
0.979909E+00	0.238800E-02	-0.708196E-01	-0.305057E+01	-0.302776E+01
0.989961E+00	0.152200E-02	-0.118911E+00	-0.651794E+01	-0.638210E+01
0.999999E+00	0.000000E+00	-0.151624E+00	0.000000E+00	0.000000E+00

Original  $\alpha$  thickness: 11.99883  
Corresponding abscissa: 0.3790650

Normalized NACA 64412 airfoil with rectified leading edge  
Revised upper surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	0.952000E+01	0.000000E+00	0.000000E+00
0.999876E-04	0.951882E-03	0.796281E+01	-0.311477E+05	-0.602605E+02
0.229971E-03	0.172379E-02	0.508383E+01	-0.131498E+05	-0.945397E+02
0.383952E-03	0.235071E-02	0.371525E+01	-0.462622E+04	-0.812265E+02
0.549932E-03	0.290364E-02	0.320541E+01	-0.151717E+04	-0.400755E+02
0.719911E-03	0.342657E-02	0.287322E+01	-0.239141E+04	-0.849298E+02
0.898889E-03	0.390252E-02	0.250782E+01	-0.169179E+04	-0.859666E+02

0.940336E+00	0.868292E-02	-0.180415E+00	0.505969E-01	0.482233E-01
0.950276E+00	0.689215E-02	-0.179678E+00	0.977655E-01	0.932152E-01
0.960214E+00	0.511137E-02	-0.178982E+00	0.422205E-01	0.402701E-01
0.970153E+00	0.333459E-02	-0.178805E+00	-0.656071E-02	-0.625820E-02
0.980093E+00	0.155681E-02	-0.180442E+00	-0.322829E+00	-0.307681E+00
0.990040E+00	-0.253969E-03	-0.193566E+00	-0.231592E+01	-0.219161E+01
0.100000E+01	-0.229672E-02	-0.205099E+00	0.000000E+00	0.000000E+00

Normalized NACA 64412 airfoil with rectified leading edge  
Revised lower surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	-0.183760E+02	0.000000E+00	0.000000E+00
0.124985E-03	-0.229672E-02	-0.158864E+02	0.398385E+05	0.987758E+01
0.749907E-03	-0.444545E-02	-0.260249E+01	0.267526E+04	0.123449E+03
0.114986E-02	-0.527235E-02	-0.191169E+01	0.779146E+03	0.775891E+02
0.151981E-02	-0.592627E-02	-0.162333E+01	0.779780E+03	0.112508E+03
0.186577E-02	-0.644120E-02	-0.140749E+01	0.467996E+03	0.909277E+02
0.219973E-02	-0.688515E-02	-0.129782E+01	0.188795E+03	0.429277E+02

PROFILE User's Guide (Appendix D, Sample 2)

0.939678E+00	0.117085E-02	0.387823E-02	-0.116642E+01	-0.116639E+01
0.949737E+00	0.115086E-02	-0.919362E-02	-0.143269E+01	-0.143251E+01
0.959797E+00	0.985878E-03	-0.249499E-01	-0.169983E+01	-0.169825E+01
0.969856E+00	0.648920E-03	-0.444896E-01	-0.218528E+01	-0.217881E+01
0.979913E+00	0.909887E-04	-0.708195E-01	-0.305097E+01	-0.302816E+01
0.989963E+00	-0.774904E-03	-0.118911E+00	-0.651876E+01	-0.638290E+01
0.100000E+01	-0.229672E-02	-0.151625E+00	0.000000E+00	0.000000E+00

Current % thickness: 11.99883  
 Corresponding abscissa: 0.3791430

# PROFILE User's Guide (Appendix D, Sample 3)

## (3) NACA 64412 Airfoil - Mode 3 (redistribute abscissas)

Here the REDISTRIBUTE option is used to reduce the number of points on the airfoil from 176 to 75 per surface. Compare with the Mode 0 and 1 examples, noting in particular the better-behaved derivatives and curvature values.

### Sample Terminal Session - Redistribute abscissas

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:

- 0 = default (no modifications) - just plot and tabulate
- 1 = rectify leading edge definition
- 2 = normalize or de-normalize geometry
- 3 = redistribute the abscissas
- 4 = modify - apply shape functions
- 5 = refine thickness/curvature
- 6 = optimize one surface (bumps + target curvatures)

Enter MODE, else <CR> for MODE = 0: 3

Enter the PROFILE control file (default is PROFILE.INP):

NACAMODE3.INP

Enter the airfoil geometry data file (default is AIRFOIL.DAT):

NORM64412.DAT

Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.\*:

NAC475PTS

Enter plot title (up to 80 chars.) <CR> uses PROFILE for the title:

NACA 64412 with redistributed abscissas (75 pts. per surface)

Enter plot subtitle (up to 80 characters) or <CR> if none:

Example 3 MODE 3

Operating modes for redistribute option:

- 1 = Read new abscissas from a file.
- 0 = Distribute points uniformly.
- 1 = Distribute points sinusoidally, bunched near the leading edge.
- 2 = Distribute points sinusoidally, near both the leading and trailing edges.
- 3 = Some other user-supplied option.

Enter mode for redistribute option (<CR> gives mode 1): 3

Enter number of points to be redistributed on the UPPER

surface (<CR> gives 100): 75

Enter number of points to be redistributed on the LOWER

surface (<CR> gives 100): 75

Original % thickness:

11.99882 Corresponding X: 0.3791430

Current % thickness:

11.99954 Corresponding X: 0.3717800

# PROFILE User's Guide (Appendix D, Sample 3)

Modified airfoil: NACA75PTS.DAT  
 Airfoil plot file: NACA75PTS.PLT  
 Tabulated results: NACA75PTS.TAB  
 Curvature OPLOT file: NACA75PTS.CRV  
 2nd derivatives file: NACA75PTS.YPP

NACA75PTS.TAB file

## Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

Operating mode: 3  
 Control file : NACA64412.INP  
 Geometry file : NORM64412.DAT  
 Output file id: NACA75PTS  
 Profiles found: 1

Normalized NACA 64412 airfoil with rectified leading edge  
 Original upper surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	0.952000E+01	0.000000E+00	0.000000E+00
0.100000E-03	0.952000E-03	0.796281E+01	-0.311438E+05	-0.602530E+02
0.200000E-03	0.172400E-02	0.508383E+01	-0.131481E+05	-0.945280E+02
0.304000E-03	0.235100E-02	0.371525E+01	-0.462564E+04	-0.812162E+02
0.550000E-03	0.290400E-02	0.320542E+01	-0.151700E+04	-0.400710E+02
0.720000E-03	0.342700E-02	0.287322E+01	-0.239113E+04	-0.849199E+02
0.899000E-03	0.390300E-02	0.250517E+01	-0.172126E+04	-0.877043E+02

0.940336E+00	0.868300E-02	-0.180441E+00	0.524747E-01	0.500124E-01
0.950276E+00	0.689200E-02	-0.179696E+00	0.975361E-01	0.929956E-01
0.960214E+00	0.511100E-02	-0.178951E+00	0.523467E-01	0.499292E-01
0.970153E+00	0.333500E-02	-0.178782E+00	-0.183018E-01	-0.174582E-01
0.980093E+00	0.155700E-02	-0.180468E+00	-0.321032E+00	-0.305964E+00
0.990040E+00	-0.254000E-03	-0.193585E+00	-0.231634E+01	-0.219197E+01
0.100000E+01	-0.229700E-02	-0.205121E+00	0.000000E+00	0.000000E+00

Normalized NACA 64412 airfoil with rectified leading edge  
 Original lower surface

X	Y	Y'	Y''	CURVATURE
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OF POOR QUALITY

PROFILE User's Guide (Appendix D, Sample 3)

0.00000E+00	0.00000E+00	-0.183760E+02	0.00000E+00	0.00000E+00
0.125000E-03	-0.229700E-02	-0.158861E+02	0.398379E+05	0.987792E+01
0.750000E-03	-0.444500E-02	-0.260186E+01	0.267181E+04	0.123367E+03
0.115000E-02	-0.527200E-02	-0.191169E+01	0.779048E+03	0.775793E+02
0.152000E-02	-0.592600E-02	-0.162333E+01	0.779694E+03	0.112495E+03
0.186600E-02	-0.644100E-02	-0.140749E+01	0.467933E+03	0.909153E+02
0.220000E-02	-0.688500E-02	-0.129782E+01	0.188787E+03	0.429259E+02

0.939678E+00	0.117100E-02	0.387944E-02	-0.116666E+01	-0.116663E+01
0.949737E+00	0.115100E-02	-0.919455E-02	-0.143281E+01	-0.143262E+01
0.959797E+00	0.986000E-03	-0.249524E-01	-0.169996E+01	-0.169838E+01
0.969856E+00	0.649000E-03	-0.444942E-01	-0.218548E+01	-0.217901E+01
0.979913E+00	0.910000E-04	-0.708318E-01	-0.305220E+01	-0.302938E+01
0.989963E+00	-0.775000E-03	-0.118925E+00	-0.651861E+01	-0.638273E+01
0.100000E+01	-0.229700E-02	-0.151639E+00	0.000000E+00	0.000000E+00

Original  $\alpha$  thickness: 11.99882  
Corresponding abscissa: 0.3791430

NACA 64412 with redistributed abscissas (75 pts. per surface)  
Revised upper surface

X	Y	Y'	Y''	CURVATURE
0.00000E+00	0.00000E+00	0.754330E+01	0.00000E+00	0.00000E+00
0.225306E-03	0.169955E-02	0.647432E+01	-0.948913E+04	-0.337509E+02
0.901043E-03	0.390802E-02	0.279598E+01	-0.139775E+04	-0.533841E+02
0.202692E-02	0.617005E-02	0.177416E+01	-0.417409E+03	-0.494151E+02
0.360250E-02	0.844729E-02	0.127823E+01	-0.212110E+03	-0.496215E+02
0.562704E-02	0.106004E-01	0.977608E+00	-0.848683E+02	-0.310303E+02
0.809956E-02	0.127582E-01	0.810713E+00	-0.501316E+02	-0.234978E+02
0.110191E-01	0.149114E-01	0.695381E+00	-0.288762E+02	-0.159803E+02
0.143841E-01	0.170879E-01	0.610365E+00	-0.216527E+02	-0.134655E+02
0.181932E-01	0.192558E-01	0.545351E+00	-0.124826E+02	-0.844677E+01
0.224448E-01	0.214615E-01	0.499810E+00	-0.894076E+01	-0.639895E+01
0.271367E-01	0.237082E-01	0.462596E+00	-0.692174E+01	-0.517475E+01
0.322670E-01	0.259904E-01	0.430709E+00	-0.550912E+01	-0.426800E+01
0.378334E-01	0.283025E-01	0.402195E+00	-0.473594E+01	-0.378209E+01
0.438333E-01	0.306304E-01	0.375827E+00	-0.405369E+01	-0.332493E+01
0.502639E-01	0.329634E-01	0.351459E+00	-0.352476E+01	-0.295976E+01
0.571226E-01	0.352910E-01	0.328857E+00	-0.306630E+01	-0.262856E+01
0.644060E-01	0.376049E-01	0.308494E+00	-0.25527E+01	-0.220336E+01
0.721110E-01	0.399069E-01	0.290392E+00	-0.217365E+01	-0.192508E+01
0.802341E-01	0.421940E-01	0.273655E+00	-0.194730E+01	-0.174739E+01
0.887715E-01	0.444594E-01	0.258247E+00	-0.166224E+01	-0.150882E+01

# PROFILE User's Guide (Appendix D, Sample 3)

0.977196E+01	0.467036E-01	0.244137E+00	-0.149161E+01	-0.136754E+01
0.107074E+00	0.489222E-01	0.230880E+00	-0.134261E+01	-0.124199E+01
0.116831E+00	0.511109E-01	0.218028E+00	-0.129193E+01	-0.120500E+01
0.126986E+00	0.532584E-01	0.205683E+00	-0.113948E+01	-0.107081E+01
0.137534E+00	0.553645E-01	0.193975E+00	-0.108033E+01	-0.102210E+01
0.148471E+00	0.574214E-01	0.182462E+00	-0.102497E+01	-0.975833E+00
0.159791E+00	0.594213E-01	0.171313E+00	-0.944675E+00	-0.904563E+00
0.171490E+00	0.613608E-01	0.160644E+00	-0.879253E+00	-0.846283E+00
0.183563E+00	0.632361E-01	0.150279E+00	-0.837947E+00	-0.810342E+00
0.196003E+00	0.650408E-01	0.140037E+00	-0.808687E+00	-0.785469E+00
0.208805E+00	0.667673E-01	0.129912E+00	-0.773005E+00	-0.753841E+00
0.221964E+00	0.684099E-01	0.119930E+00	-0.742111E+00	-0.728438E+00
0.235474E+00	0.699622E-01	0.110014E+00	-0.723720E+00	-0.710777E+00
0.249328E+00	0.714169E-01	0.100166E+00	-0.697939E+00	-0.687565E+00
0.263520E+00	0.727681E-01	0.903938E-01	-0.679115E+00	-0.670876E+00
0.278044E+00	0.740094E-01	0.804994E-01	-0.683312E+00	-0.676723E+00
0.292803E+00	0.751294E-01	0.707383E-01	-0.631280E+00	-0.626571E+00
0.308061E+00	0.761297E-01	0.610919E-01	-0.640651E+00	-0.637082E+00
0.323541E+00	0.769987E-01	0.513709E-01	-0.615343E+00	-0.612915E+00
0.339325E+00	0.777329E-01	0.412565E-01	-0.666289E+00	-0.664592E+00
0.355407E+00	0.783102E-01	0.300269E-01	-0.730244E+00	-0.729258E+00
0.371780E+00	0.787703E-01	0.175794E-01	-0.790288E+00	-0.789921E+00
0.388436E+00	0.788871E-01	0.395315E-02	-0.846957E+00	-0.845908E+00
0.405367E+00	0.788328E-01	-0.103781E-01	-0.845928E+00	-0.846821E+00
0.422566E+00	0.785291E-01	-0.244216E-01	-0.786121E+00	-0.785419E+00
0.440025E+00	0.779829E-01	-0.375337E-01	-0.715901E+00	-0.714391E+00
0.457737E+00	0.772058E-01	-0.495646E-01	-0.642647E+00	-0.640286E+00
0.475693E+00	0.762122E-01	-0.606254E-01	-0.589335E+00	-0.586101E+00
0.493885E+00	0.750118E-01	-0.710950E-01	-0.561647E+00	-0.557416E+00
0.512305E+00	0.736069E-01	-0.809918E-01	-0.512934E+00	-0.507928E+00
0.530945E+00	0.720081E-01	-0.903585E-01	-0.492074E+00	-0.486108E+00
0.549796E+00	0.702173E-01	-0.993504E-01	-0.461887E+00	-0.455132E+00
0.568850E+00	0.682404E-01	-0.107980E+00	-0.443820E+00	-0.436169E+00
0.588099E+00	0.660798E-01	-0.116178E+00	-0.407991E+00	-0.399868E+00
0.607533E+00	0.637449E-01	-0.123912E+00	-0.387955E+00	-0.379189E+00
0.627144E+00	0.612403E-01	-0.131302E+00	-0.365760E+00	-0.356501E+00
0.646922E+00	0.585718E-01	-0.138312E+00	-0.343030E+00	-0.333417E+00
0.666860E+00	0.557460E-01	-0.144891E+00	-0.317012E+00	-0.307285E+00
0.686948E+00	0.527714E-01	-0.151110E+00	-0.302164E+00	-0.292102E+00
0.707177E+00	0.496528E-01	-0.156956E+00	-0.275782E+00	-0.265896E+00
0.727538E+00	0.463999E-01	-0.162333E+00	-0.252410E+00	-0.242751E+00
0.748022E+00	0.430217E-01	-0.167150E+00	-0.217968E+00	-0.209142E+00
0.768619E+00	0.395326E-01	-0.171387E+00	-0.193389E+00	-0.185170E+00
0.789321E+00	0.359432E-01	-0.175052E+00	-0.160669E+00	-0.153557E+00
0.810117E+00	0.322680E-01	-0.177899E+00	-0.113201E+00	-0.108032E+00
0.830999E+00	0.285285E-01	-0.179936E+00	-0.818543E-01	-0.780340E-01
0.851957E+00	0.247394E-01	-0.181298E+00	-0.480779E-01	-0.458013E-01
0.872982E+00	0.209170E-01	-0.181958E+00	-0.147017E-01	-0.140007E-01
0.894064E+00	0.170777E-01	-0.182030E+00	0.783478E-02	0.746090E-02

# PROFILE User's Guide (Appendix D, Sample 3)

0.915194E+00	0.132331E-01	-0.181495E+00	0.427829E-01	0.407528E-01
0.936362E+00	0.940082E-02	-0.180509E+00	0.504385E-01	0.480701E-01
0.957559E+00	0.558598E-02	-0.179390E+00	0.550926E-01	0.525363E-01
0.978775E+00	0.179247E-02	-0.185736E+00	-0.653289E+00	-0.620885E+00
0.100000E+01	-0.229700E-02	-0.192669E+00	0.000000E+00	0.000000E+00

NACA 64412 with redistributed abscissas (75 pts. per surface)  
Revised lower surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	-0.124078E+02	0.000000E+00	0.000000E+00
0.225306E-03	-0.279555E-02	-0.100474E+02	0.209528E+05	0.203542E+02
0.901043E-03	-0.480124E-02	-0.247337E+01	0.146440E+04	0.771195E+02
0.202692E-02	-0.665781E-02	-0.143673E+01	0.377086E+03	0.703018E+02
0.360250E-02	-0.845345E-02	-0.100776E+01	0.167429E+03	0.585086E+02
0.562704E-02	-0.101506E-01	-0.759422E+00	0.779049E+02	0.393489E+02
0.809956E-02	-0.117901E-01	-0.605086E+00	0.469357E+02	0.293945E+02
0.110191E-01	-0.133567E-01	-0.487640E+00	0.335210E+02	0.243414E+02
0.143841E-01	-0.148078E-01	-0.396541E+00	0.206228E+02	0.165657E+02
0.181932E-01	-0.161687E-01	-0.330348E+00	0.141320E+02	0.120984E+02
0.224448E-01	-0.174454E-01	-0.283506E+00	0.790348E+01	0.703811E+01
0.271367E-01	-0.186886E-01	-0.252599E+00	0.527084E+01	0.480381E+01
0.322670E-01	-0.199152E-01	-0.228830E+00	0.399521E+01	0.370077E+01
0.378334E-01	-0.211270E-01	-0.209188E+00	0.306219E+01	0.287165E+01
0.438333E-01	-0.223270E-01	-0.192123E+00	0.262596E+01	0.248700E+01
0.502639E-01	-0.235082E-01	-0.176205E+00	0.232473E+01	0.222052E+01
0.571226E-01	-0.246620E-01	-0.161382E+00	0.199773E+01	0.192215E+01
0.644060E-01	-0.257845E-01	-0.148046E+00	0.166439E+01	0.161113E+01
0.721110E-01	-0.268757E-01	-0.136344E+00	0.137289E+01	0.133547E+01
0.802341E-01	-0.279380E-01	-0.126189E+00	0.112751E+01	0.110110E+01
0.887715E-01	-0.289742E-01	-0.117284E+00	0.958537E+00	0.939094E+00
0.977196E-01	-0.299853E-01	-0.109113E+00	0.867782E+00	0.852513E+00
0.107074E+00	-0.309681E-01	-0.102055E+00	0.641325E+00	0.631435E+00
0.116831E+00	-0.319333E-01	-0.952143E-01	0.760796E+00	0.750566E+00
0.126986E+00	-0.328609E-01	-0.884274E-01	0.575933E+00	0.569244E+00
0.137534E+00	-0.337616E-01	-0.823107E-01	0.583844E+00	0.577960E+00
0.148471E+00	-0.346269E-01	-0.762453E-01	0.525284E+00	0.520737E+00
0.159791E+00	-0.354564E-01	-0.703273E-01	0.520337E+00	0.516500E+00
0.171490E+00	-0.362436E-01	-0.647395E-01	0.434893E+00	0.432173E+00
0.183563E+00	-0.369934E-01	-0.593878E-01	0.451703E+00	0.449324E+00
0.196003E+00	-0.376973E-01	-0.540335E-01	0.409049E+00	0.407264E+00
0.208805E+00	-0.383555E-01	-0.488083E-01	0.407251E+00	0.405800E+00
0.221964E+00	-0.389625E-01	-0.435816E-01	0.387121E+00	0.386021E+00
0.235474E+00	-0.395159E-01	-0.383026E-01	0.394434E+00	0.393568E+00
0.249328E+00	-0.400087E-01	-0.329832E-01	0.373522E+00	0.372913E+00
0.263520E+00	-0.404392E-01	-0.276828E-01	0.373386E+00	0.372957E+00
0.278044E+00	-0.408019E-01	-0.223005E-01	0.367732E+00	0.367458E+00

# PROFILE User's Guide (Appendix D, Sample 3)

0.292893E+00	-0.410925E-01	-0.169122E-01	0.358016E+00	0.357862E+00
0.308061E+00	-0.413079E-01	-0.115945E-01	0.343169E+00	0.343100E+00
0.323541E+00	-0.414462E-01	-0.624155E-02	0.348437E+00	0.348417E+00
0.339325E+00	-0.415013E-01	-0.425893E-03	0.388465E+00	0.388465E+00
0.355407E+00	-0.414579E-01	0.639991E-02	0.460401E+00	0.460373E+00
0.371780E+00	-0.412915E-01	0.145013E-01	0.529232E+00	0.529065E+00
0.388436E+00	-0.409765E-01	0.238940E-01	0.598605E+00	0.598093E+00
0.405367E+00	-0.404862E-01	0.341208E-01	0.609449E+00	0.608386E+00
0.422566E+00	-0.398092E-01	0.440714E-01	0.547661E+00	0.546069E+00
0.440025E+00	-0.389563E-01	0.530830E-01	0.484621E+00	0.482580E+00
0.457737E+00	-0.379401E-01	0.609354E-01	0.402124E+00	0.399894E+00
0.475693E+00	-0.367811E-01	0.676144E-01	0.341823E+00	0.339493E+00
0.493885E+00	-0.354945E-01	0.736091E-01	0.317212E+00	0.314651E+00
0.512305E+00	-0.340848E-01	0.789872E-01	0.266705E+00	0.264228E+00
0.530945E+00	-0.325661E-01	0.837604E-01	0.245454E+00	0.242893E+00
0.549796E+00	-0.309435E-01	0.879772E-01	0.201924E+00	0.199602E+00
0.568850E+00	-0.292305E-01	0.916569E-01	0.184303E+00	0.182005E+00
0.588099E+00	-0.274321E-01	0.948325E-01	0.145659E+00	0.143716E+00
0.607533E+00	-0.255616E-01	0.973913E-01	0.117677E+00	0.116023E+00
0.627144E+00	-0.236291E-01	0.994230E-01	0.895199E-01	0.882087E-01
0.646922E+00	-0.216451E-01	0.100840E+00	0.537216E-01	0.529125E-01
0.666860E+00	-0.196239E-01	0.101614E+00	0.240115E-01	0.236444E-01
0.686948E+00	-0.175778E-01	0.101837E+00	-0.186526E-02	-0.183661E-02
0.707177E+00	-0.155182E-01	0.101369E+00	-0.444329E-01	-0.437567E-01
0.727538E+00	-0.134634E-01	0.100104E+00	-0.797771E-01	-0.785927E-01
0.748022E+00	-0.114296E-01	0.979148E-01	-0.133990E+00	-0.132086E+00
0.768619E+00	-0.944128E-02	0.947141E-01	-0.176797E+00	-0.174444E+00
0.789321E+00	-0.751844E-02	0.904151E-01	-0.238543E+00	-0.235648E+00
0.810117E+00	-0.568971E-02	0.846813E-01	-0.312876E+00	-0.309540E+00
0.830999E+00	-0.398961E-02	0.774100E-01	-0.383534E+00	-0.380112E+00
0.851957E+00	-0.245147E-02	0.684815E-01	-0.468510E+00	-0.465233E+00
0.872982E+00	-0.111521E-02	0.575882E-01	-0.567718E+00	-0.564905E+00
0.894064E+00	-0.272941E-04	0.443538E-01	-0.687788E+00	-0.685763E+00
0.915194E+00	0.756357E-03	0.278663E-01	-0.872800E+00	-0.871785E+00
0.936362E+00	0.115069E-02	0.662382E-02	-0.113423E+01	-0.113416E+01
0.957559E+00	0.103629E-02	-0.232019E-01	-0.167996E+01	-0.167861E+01
0.978775E+00	0.165955E-03	-0.785220E-01	-0.353503E+01	-0.350258E+01
0.100000E+01	-0.229700E-02	-0.116038E+00	0.000000E+00	0.000000E+00

Current % thickness: 11.99954  
Corresponding abscissa: 0.3717800



# PROFILE User's Guide (Appendix D, Sample 4)

## (4) NACA 6-Series Airfoil - Mode 4 (shape functions)

In this example, two shape functions are added to the airfoil. The exponential bump (function 5) is added to the upper surface to blunt the leading edge, and the trailing bump (function 2) is added to both surfaces with a negative multiplier to deflect the trailing edge. The resulting airfoil plot and corresponding .PLT file are shown.

Sample Terminal Session - Apply shape functions

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:

- 0 = default (no modifications) - just plot and tabulate
- 1 = rectify leading edge definition
- 2 = normalize or de-normalize geometry
- 3 = redistribute the abscissas
- 4 = modify - apply shape functions
- 5 = refine thickness/curvature
- 6 = optimize one surface (bumps + target curvatures)

Enter MODE, else <CR> for MODE = 0: 4

Enter the PROFILE control file (default is PROFILE.INP):

NACA64412.INP

Enter the airfoil geometry data file (default is AIRFOIL.DAT):

NACA75PTS.DAT

Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.\*\*:

NACAMOD

Enter plot title (up to 80 chars.) <CR> uses PROFILE for the title:

Modified NACA 64412 Airfoil

Enter plot subtitle (up to 80 characters) or <CR> if none:

Blunted leading edge, deflected trailing edge

The following shape functions are available for modifying

geometry data.

- |             |  |
|-------------|--|
| SCALE       | 1: Y = Y * P1                                    |
| TRAILING    | 2: Y = X ** P1                                   |
| DROOP       | 3: Y = e ** (-P1 * X)                            |
| LEADING     | 4: Y = (1. - X) ** P1                            |
| EXPONENTIAL | 5: Y = X ** P1 * (1. - X) * e ** (-P2 * X)       |
| SINE        | 6: Y = SIN ** P2 (PI * X ** (LOG(.5)/LOG(P1)))   |
| WAGNER      | 7: Wagner function; P1 = Order of requested term |

You may specify shape function multipliers in addition to the necessary parameters. Enter 0 to repeat the menu. To quit or start over (on the current surface), hit CTRL Z.

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# PROFILE User's Guide (Appendix D, Sample 4)

Enter the number of the first shape function you wish to add to the UPPER surface. If none for this surface hit RETURN. 5  
 Enter P1 for shape function 5: 5  
 Enter P2 for shape function 5: 10.  
 Enter shape function multiplier: .1

Next shape function for UPPER surface? (If none hit RETURN.) 2  
 Enter P1 for shape function 2: .5  
 Enter shape function multiplier: -.01

Next shape function for UPPER surface? (If none hit RETURN.) <CR>

Enter the number of the first shape function you wish to add to the LOWER surface. If none for this surface hit RETURN. 2  
 Enter P1 for shape function 2: 5.  
 Enter shape function multiplier: -.01

Next shape function for LOWER surface? (If none hit RETURN.) <CR>

Original % thickness: 11.99950 Corresponding X: 0.3717800  
 Current % thickness: 12.09253 Corresponding X: 0.3717800

Modified airfoil: NACAMOD.DAT  
 Airfoil plot file: NACAMOD.PLT  
 Tabulated results: NACAMOD.TAB  
 Curvature QPLOT file: NACAMOD.CRV  
 2nd derivatives file: NACAMOD.YPP

---

NACAMOD.PLT file (QPLOT file for plotting airfoil geometry)

---

Modified NACA 64412 Airfoil

Blunted leading edge, deflected trailing edge

X/C  
 Y/C

\$OPTIONS

XMIN = 0.000000.

XMAX = 1.000000.

YMIN = -0.041501.

YMAX = 0.078887.

WIDTH = 6.400000.

HEIGHT = 1.280000.

LEGEND = 'NACA 64412 with redistributed abscissas (75 pts. per surface)

LINE = 'SOLID

\$END

0.0000000E+00 0.0000000E+00

2.2500000E-04 1.7020000E-03

9.0099999E-04 3.9080000E-03

PROFILE User's Guide (Appendix D, Sample 4)

2.0270001E-03 6.1699999E-03  
 3.6030000E-03 8.4480001E-03  
 5.6269998E-03 1.0600000E-02  
 8.1000002E-03 1.2758000E-02  
 1.1019000E-02 1.4919000E-02  
 1.4384000E-02 1.7082000E-02  
 1.8193001E-02 1.9254999E-02  
 2.2445001E-02 2.1462001E-02  
 2.7137000E-02 2.3708001E-02  
 3.2267001E-02 2.5990000E-02  
 3.7833001E-02 2.8302001E-02  
 4.3832999E-02 3.0630000E-02  
 5.0264001E-02 3.2963000E-02  
 5.7123002E-02 3.5291001E-02  
 6.4406000E-02 3.7604999E-02  
 7.2111003E-02 3.9907001E-02  
 8.0233999E-02 4.2194001E-02  
 8.8771999E-02 4.4459999E-02  
 9.7719997E-02 4.6705000E-02  
 0.1070740 4.8923001E-02  
 0.1168310 5.1109999E-02  
 0.1269860 5.3259000E-02  
 0.1375340 5.5365000E-02  
 0.1484710 5.7420999E-02  
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 0.1835630 6.3235998E-02  
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 0.3235410 7.6999001E-02  
 0.3393250 7.7733003E-02  
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 0.3884360 7.8887001E-02  
 0.4053670 7.8832999E-02  
 0.4225660 7.8529000E-02  
 0.4400250 7.7982999E-02  
 0.4577370 7.7206001E-02  
 0.4756930 7.6211996E-02  
 0.4938850 7.5011998E-02  
 0.5123050 7.3606998E-02  
 0.5309450 7.2007999E-02

PROFILE User's Guide (Appendix D, Sample 4)

```

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0.5688500      6.8240002E-02
0.5880990      6.6079997E-02
0.6075330      6.3744999E-02
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0.6469220      5.8572002E-02
0.6668600      5.5746000E-02
0.6869480      5.2709998E-02
0.7071770      4.9653001E-02
0.7275380      4.6399999E-02
0.7480220      4.3021999E-02
0.7686190      3.9533000E-02
0.7893210      3.5943002E-02
0.8101170      3.2267999E-02
0.8309990      2.8527999E-02
0.8519570      2.4738999E-02
0.8729820      2.0917000E-02
0.8940640      1.7077999E-02
0.9151940      1.3233000E-02
0.9363620      9.4010001E-03
0.9575590      5.5860002E-03
0.9787750      1.7920000E-03
1.000000      -2.2970000E-03

```

END CURVE

\$OPTIONS

LINE = 'SOLID

\$END

```

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9.0099999E-04 -4.6290001E-03
2.0270001E-03 -6.6610002E-03
3.6030000E-03 -8.4530003E-03
5.6269998E-03 -1.0151000E-02
8.1000002E-03 -1.1790000E-02
1.1019000E-02 -1.3357000E-02
1.4384000E-02 -1.4809000E-02
1.8193001E-02 -1.6164999E-02
2.2445001E-02 -1.7445000E-02
2.7137000E-02 -1.8688999E-02
3.2267001E-02 -1.9915000E-02
3.7833001E-02 -2.1127000E-02
4.3832999E-02 -2.2327000E-02
5.0264001E-02 -2.3507999E-02
5.7123002E-02 -2.4661999E-02
6.4406000E-02 -2.5784001E-02
7.2111003E-02 -2.6876001E-02
8.0233999E-02 -2.7938001E-02
8.8771999E-02 -2.8974000E-02
9.7719997E-02 -2.9984999E-02

```

0.1070740	-3.0972000E-02
0.1168310	-3.1931002E-02
0.1269860	-3.2862000E-02
0.1375340	-3.3760998E-02
0.1484710	-3.4627002E-02
0.1597910	-3.5456002E-02
0.1714900	-3.6244001E-02
0.1835630	-3.6993001E-02
0.1960030	-3.7696999E-02
0.2088050	-3.8355000E-02
0.2219640	-3.8963001E-02
0.2354740	-3.9515998E-02
0.2493280	-4.0008999E-02
0.2635200	-4.0438998E-02
0.2780440	-4.0801998E-02
0.2928930	-4.1092999E-02
0.3080610	-4.1308001E-02
0.3235410	-4.1446000E-02
0.3393250	-4.1501001E-02
0.3554070	-4.1457999E-02
0.3717800	-4.1290998E-02
0.3884360	-4.0977001E-02
0.4053670	-4.0486000E-02
0.4225660	-3.9809000E-02
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0.5123050	-3.4085002E-02
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0.5880990	-2.7432000E-02
0.6075330	-2.5562000E-02
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0.7275380	-1.3463000E-02
0.7480220	-1.1430000E-02
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0.8101170	-5.6900000E-03
0.8309990	-3.9900001E-03
0.8519570	-2.4510000E-03
0.8729820	-1.1150000E-03
0.8940640	-2.7000000E-05
0.9151940	7.5599999E-04

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PROFILE User's Guide (Appendix D, Sample 4)

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 0.9575590 1.0360000E-03  
 0.9787750 1.6400000E-04  
 1.000000 -2.2970000E-03

END CURVE

\$OPTIONS

XMIN = 0.000000,

XMAX = 1.000000,

YMIN = -0.041501,

YMAX = 0.078887,

WIDTH = 6.400000,

HEIGHT = 1.280000,

LEGEND = 'Revised profile',

LINE = 'DASH',

\$END

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 9.009999E-04 6.880626E-03  
 2.027001E-03 1.0572937E-02  
 3.603000E-03 1.4217218E-02  
 5.626998E-03 1.7650990E-02  
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 1.101900E-02 2.4217313E-02  
 1.438400E-02 2.7319143E-02  
 1.8193001E-02 3.0294951E-02  
 2.2445001E-02 3.3163019E-02  
 2.713700E-02 3.5925385E-02  
 3.2267001E-02 3.8579285E-02  
 3.7833001E-02 4.1121740E-02  
 4.3832999E-02 4.3544274E-02  
 5.0264001E-02 4.5843642E-02  
 5.7123002E-02 4.8019532E-02  
 6.440600E-02 5.0074197E-02  
 7.2111003E-02 5.2021962E-02  
 8.023399E-02 5.3872947E-02  
 8.877199E-02 5.5634573E-02  
 9.7719997E-02 5.7320412E-02  
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 0.1375340 6.3448846E-02  
 0.1484710 6.4854212E-02  
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 0.1714900 6.7534640E-02  
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 0.1960030 7.0051774E-02  
 0.2088050 7.1243517E-02  
 0.2219640 7.2387189E-02  
 0.2354740 7.3476143E-02

0.2493280	7.4504912E-02
0.2635200	7.5466201E-02
0.2780440	7.6353073E-02
0.2928930	7.7153049E-02
0.3080610	7.7866241E-02
0.3235410	7.8477412E-02
0.3393250	7.8981102E-02
0.3554070	7.9352640E-02
0.3717800	7.9563297E-02
0.3884360	7.9582259E-02
0.4053670	7.9380728E-02
0.4225660	7.8942880E-02
0.4400250	7.8273974E-02
0.4577370	7.7382267E-02
0.4756930	7.6279119E-02
0.4938850	7.4972920E-02
0.5123050	7.3462076E-02
0.5309450	7.1755067E-02
0.5497960	6.9851354E-02
0.5688500	6.7754418E-02
0.5880990	6.5464705E-02
0.6075330	6.2987670E-02
0.6271440	6.0325649E-02
0.6469220	5.7482954E-02
0.6668600	5.4461773E-02
0.6869480	5.1268212E-02
0.7071770	4.7905255E-02
0.7275380	4.4377740E-02
0.7480220	4.0692374E-02
0.7686190	3.6859717E-02
0.7893210	3.2886133E-02
0.8101170	2.8783878E-02
0.8309990	2.4568986E-02
0.8519570	2.0253358E-02
0.8729820	1.5848702E-02
0.8940640	1.1366590E-02
0.9151940	6.8134069E-03
0.9363620	2.2034105E-03
0.9575590	-2.4643014E-03
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END CURVE

\$OPTIONS

LINE = 'DASH

\$END

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9.009999E-04	-4.629000E-03
2.027000E-03	-6.661000E-03

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 5.6269998E-03 -1.0151000E-02  
 8.1000002E-03 -1.1790000E-02  
 1.1019000E-02 -1.3357000E-02  
 1.4384000E-02 -1.4809000E-02  
 1.8193001E-02 -1.6164999E-02  
 2.2445001E-02 -1.7445000E-02  
 2.7137000E-02 -1.8688999E-02  
 3.2267001E-02 -1.9915000E-02  
 3.7833001E-02 -2.1127000E-02  
 4.3832999E-02 -2.2327002E-02  
 5.0264001E-02 -2.3508003E-02  
 5.7123002E-02 -2.4662005E-02  
 6.4406000E-02 -2.5784012E-02  
 7.2111003E-02 -2.6876019E-02  
 8.0233999E-02 -2.7938034E-02  
 8.8771999E-02 -2.8974056E-02  
 9.7719997E-02 -2.9985089E-02  
 0.1070740 -3.0972142E-02  
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 0.1375340 -3.3761490E-02  
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 0.1714900 -3.6245484E-02  
 0.1835630 -3.6995083E-02  
 0.1960030 -3.7699893E-02  
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 0.2780440 -4.0818617E-02  
 0.2928930 -4.1114554E-02  
 0.3080610 -4.135747E-02  
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 0.3393250 -4.1545987E-02  
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 0.3717800 -4.1362025E-02  
 0.3884360 -4.1065432E-02  
 0.4053670 -4.0595457E-02  
 0.4225660 -3.9943732E-02  
 0.4400250 -3.9120965E-02  
 0.4577370 -3.8140945E-02  
 0.4756930 -3.7024576E-02  
 0.4938850 -3.5787851E-02  
 0.5123050 -3.4437895E-02  
 0.5309450 -3.2987937E-02  
 0.5497960 -3.1446353E-02



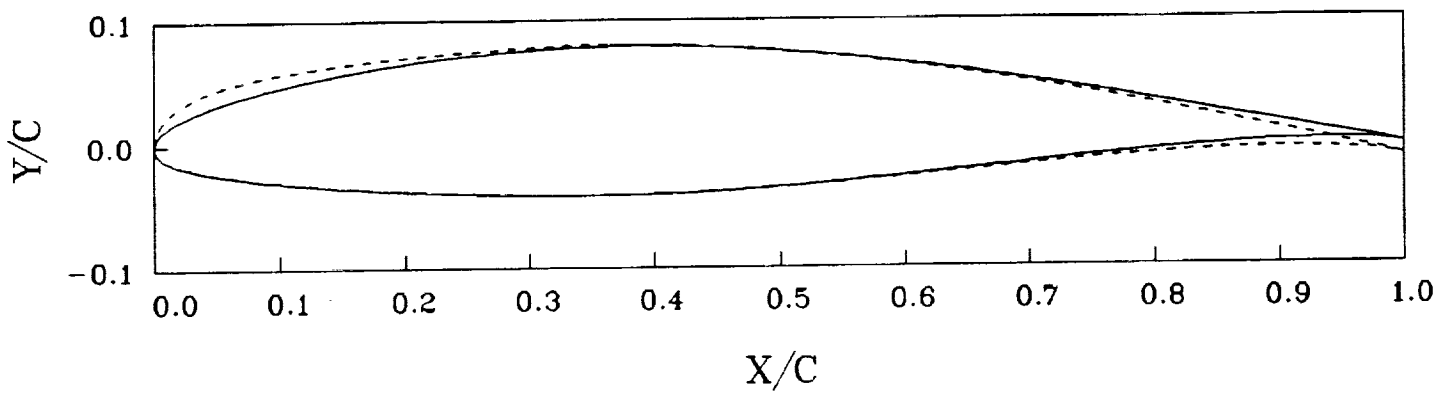
PROFILE User's Guide (Appendix D, Sample 4)

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0.5880990	-2.8135480E-02
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0.8729820	-6.1852164E-03
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0.9575590	-7.0145898E-03
0.9787750	-8.8188546E-03
1.000000	-1.2297000E-02
END FRAME	

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Modified NACA 64412 Airfoil  
Blunted leading edge, deflected trailing edge

NACA 64412 with redistributed abscissas (75 pts. per surface)  
Revised profile -----



# PROFILE User's Guide (Appendix D, Sample 4)

NACAMOD.TAB file

Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

Operating mode: 4  
Control file : NACA64412.INP  
Geometry file : NACA75PTS.DAT  
Output file id: NACAMOD  
Profiles found: 1

The following shape functions and parameters  
were selected for the UPPER surface:

EXPONENTIAL 5:  $Y = X ** P1 * (1. - X) * e ** (-P2 * X)$   
P1 = 0.500000  
P2 = 10.000000  
Shape function multiplier = 0.100000

TRAILING 2:  $Y = X ** P1$   
P1 = 5.000000  
Shape function multiplier = -0.010000

The following shape functions and parameters  
were selected for the LOWER surface:

TRAILING 2:  $Y = X ** P1$   
P1 = 5.000000  
Shape function multiplier = -0.010000

NACA 64412 with redistributed abscissas (75 pts. per surface)  
Original upper surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	0.755556E+01	0.000000E+00	0.000000E+00
0.225000E-03	0.170000E-02	0.648443E+01	-0.952116E+04	-0.337104E+02
0.901000E-03	0.390800E-02	0.279458E+01	-0.139555E+04	-0.533712E+02
0.202700E-02	0.617000E-02	0.177381E+01	-0.417531E+03	-0.494516E+02
0.360300E-02	0.844700E-02	0.127798E+01	-0.211701E+03	-0.495440E+02
0.562700E-02	0.106000E-01	0.977720E+00	-0.849950E+02	-0.310714E+02
0.810000E-02	0.127580E-01	0.810688E+00	-0.500901E+02	-0.234792E+02
0.872982E+00	0.209170E-01	-0.181941E+00	-0.149699E-01	-0.142562E-01
0.894064E+00	0.170780E-01	-0.182034E+00	0.614462E-02	0.585138E-02

# PROFILE User's Guide (Appendix D, Sample 4)

0.915194E+00	0.132330E-01	-0.181499E+00	0.445163E-01	0.424038E-01
0.936362E+00	0.940100E-02	-0.180503E+00	0.495186E-01	0.471935E-01
0.957559E+00	0.558600E-02	-0.179403E+00	0.543040E-01	0.517840E-01
0.978775E+00	0.179200E-02	-0.185737E+00	-0.651416E+00	-0.619104E+00
0.100000E+01	-0.229700E-02	-0.192650E+00	0.000000E+00	0.000000E+00

NACA 64412 with redistributed abscissas (75 pts. per surface)  
Original lower surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	-0.124267E+02	0.000000E+00	0.000000E+00
0.225000E-03	-0.279600E-02	-0.100641E+02	0.210004E+05	0.203002E+02
0.901000E-03	-0.480100E-02	-0.247200E+01	0.146146E+04	0.770743E+02
0.202700E-02	-0.665800E-02	-0.143657E+01	0.377676E+03	0.704278E+02
0.360300E-02	-0.845300E-02	-0.100761E+01	0.166682E+03	0.582617E+02
0.562700E-02	-0.101510E-01	-0.759640E+00	0.783525E+02	0.395624E+02
0.810000E-02	-0.117900E-01	-0.605001E+00	0.467098E+02	0.292563E+02

0.872982E+00	-0.111500E-02	0.575838E-01	-0.566906E+00	-0.564098E+00
0.894064E+00	-0.270000E-04	0.443405E-01	-0.689457E+00	-0.687429E+00
0.915194E+00	0.756000E-03	0.278666E-01	-0.869837E+00	-0.868824E+00
0.936362E+00	0.115100E-02	0.662566E-02	-0.113705E+01	-0.113697E+01
0.957559E+00	0.103600E-02	-0.232080E-01	-0.167785E+01	-0.167650E+01
0.978775E+00	0.166000E-03	-0.785167E-01	-0.353601E+01	-0.350356E+01
0.100000E+01	-0.229700E-02	-0.116043E+00	0.000000E+00	0.000000E+00

Original % thickness: 11.99950  
Corresponding abscissa: 0.3717800

Modified NACA 64412 Airfoil  
Revised upper surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	0.142057E+02	0.000000E+00	0.000000E+00
0.225000E-03	0.319629E-02	0.120191E+02	-0.194370E+05	-0.110796E+02
0.901000E-03	0.688006E-02	0.463542E+01	-0.240813E+04	-0.225829E+02
0.202700E-02	0.105729E-01	0.287628E+01	-0.716443E+03	-0.253718E+02
0.360300E-02	0.142162E-01	0.204262E+01	-0.341503E+03	-0.290314E+02
0.562700E-02	0.176510E-01	0.154101E+01	-0.154159E+03	-0.248664E+02
0.810000E-02	0.209905E-01	0.123679E+01	-0.918726E+02	-0.228346E+02
0.110190E-01	0.242093E-01	0.102060E+01	-0.562552E+02	-0.192840E+02
0.143840E-01	0.273251E-01	0.857446E+00	-0.407046E+02	-0.178074E+02
0.181930E-01	0.302960E-01	0.730019E+00	-0.262143E+02	-0.138120E+02

PROFILE User's Guide (Appendix D, Sample 4)

0.224450E+01	0.331630E-01	0.633617E+00	-0.191294E+02	-0.115299E+02
0.271370E-01	0.359254E-01	0.554627E+00	-0.145409E+02	-0.972463E+01
0.322670E-01	0.385793E-01	0.488290E+00	-0.113214E+02	-0.821473E+01
0.378330E-01	0.411217E-01	0.431264E+00	-0.916957E+01	-0.709951E+01
0.438330E-01	0.435443E-01	0.381451E+00	-0.743483E+01	-0.606423E+01
0.502640E-01	0.458436E-01	0.338037E+00	-0.606676E+01	-0.515789E+01
0.571230E-01	0.480195E-01	0.300201E+00	-0.496584E+01	-0.436295E+01
0.644060E-01	0.500742E-01	0.267868E+00	-0.391313E+01	-0.352681E+01
0.721110E-01	0.520220E-01	0.240660E+00	-0.314912E+01	-0.289409E+01
0.802340E-01	0.538729E-01	0.217310E+00	-0.259996E+01	-0.242609E+01
0.887720E-01	0.556336E-01	0.197516E+00	-0.203673E+01	-0.192310E+01
0.977200E-01	0.573194E-01	0.180819E+00	-0.169538E+01	-0.161551E+01
0.107074E+00	0.589366E-01	0.166481E+00	-0.137046E+01	-0.131539E+01
0.116831E+00	0.604957E-01	0.153864E+00	-0.121571E+01	-0.117378E+01
0.126986E+00	0.619955E-01	0.142829E+00	-0.957474E+00	-0.928905E+00
0.137534E+00	0.634488E-01	0.133222E+00	-0.864126E+00	-0.841621E+00
0.148471E+00	0.648542E-01	0.124430E+00	-0.743638E+00	-0.726696E+00
0.159791E+00	0.662151E-01	0.116567E+00	-0.645761E+00	-0.632820E+00
0.171490E+00	0.675346E-01	0.109417E+00	-0.576493E+00	-0.566294E+00
0.183563E+00	0.688136E-01	0.102782E+00	-0.522698E+00	-0.514523E+00
0.196003E+00	0.700518E-01	0.963569E-01	-0.510292E+00	-0.503267E+00
0.208805E+00	0.712435E-01	0.900432E-01	-0.475997E+00	-0.470266E+00
0.221964E+00	0.723872E-01	0.837990E-01	-0.473060E+00	-0.468120E+00
0.235474E+00	0.734761E-01	0.774709E-01	-0.463829E+00	-0.459684E+00
0.249328E+00	0.745049E-01	0.710355E-01	-0.465130E+00	-0.461794E+00
0.263520E+00	0.754662E-01	0.644371E-01	-0.464673E+00	-0.487076E+00
0.278044E+00	0.763531E-01	0.575082E-01	-0.489495E+00	-0.454951E+00
0.292893E+00	0.771530E-01	0.504831E-01	-0.456691E+00	-0.490511E+00
0.308061E+00	0.778662E-01	0.432890E-01	-0.491890E+00	-0.483301E+00
0.323541E+00	0.784774E-01	0.357331E-01	-0.552859E+00	-0.552230E+00
0.339325E+00	0.789811E-01	0.275481E-01	-0.552859E+00	-0.630528E+00
0.355407E+00	0.793526E-01	0.180304E-01	-0.630836E+00	-0.710126E+00
0.371780E+00	0.795633E-01	0.705237E-02	-0.776593E+00	-0.776560E+00
0.388436E+00	0.795823E-01	-0.532891E-02	-0.794318E+00	-0.793905E+00
0.405367E+00	0.793807E-01	-0.186269E-01	-0.794318E+00	-0.740722E+00
0.422566E+00	0.789429E-01	-0.318372E-01	-0.741848E+00	-0.682201E+00
0.440025E+00	0.782740E-01	-0.442855E-01	-0.684209E+00	-0.619031E+00
0.457737E+00	0.773823E-01	-0.558526E-01	-0.621930E+00	-0.569669E+00
0.475693E+00	0.762791E-01	-0.665845E-01	-0.573462E+00	-0.553432E+00
0.493885E+00	0.749729E-01	-0.768793E-01	-0.558345E+00	-0.509936E+00
0.512305E+00	0.734621E-01	-0.867716E-01	-0.515706E+00	-0.495080E+00
0.530945E+00	0.717551E-01	-0.962562E-01	-0.501976E+00	-0.470409E+00
0.549796E+00	0.698514E-01	-0.105496E+00	-0.478283E+00	-0.455715E+00
0.568850E+00	0.677544E-01	-0.114480E+00	-0.464702E+00	-0.430021E+00
0.588099E+00	0.654647E-01	-0.123185E+00	-0.439844E+00	-0.413467E+00
0.607533E+00	0.629877E-01	-0.131581E+00	-0.424251E+00	-0.394046E+00
0.627144E+00	0.603256E-01	-0.139719E+00	-0.405641E+00	-0.380249E+00
0.646922E+00	0.574830E-01	-0.147614E+00	-0.392745E+00	-0.359168E+00
0.666860E+00	0.544618E-01	-0.155240E+00	-0.372230E+00	

# PROFILE User's Guide (Appendix D, Sample 4)

0.686948E+00	0.512682E-01	-0.162599E+00	-0.360468E+00	-0.346631E+00
0.707177E+00	0.479053E-01	-0.169735E+00	-0.345103E+00	-0.330709E+00
0.727538E+00	0.443777E-01	-0.176571E+00	-0.326385E+00	-0.311695E+00
0.748022E+00	0.406924E-01	-0.182988E+00	-0.300112E+00	-0.285645E+00
0.768619E+00	0.368597E-01	-0.189003E+00	-0.283961E+00	-0.269398E+00
0.789321E+00	0.328861E-01	-0.194596E+00	-0.256378E+00	-0.242475E+00
0.810117E+00	0.287839E-01	-0.199548E+00	-0.219848E+00	-0.207342E+00
0.830999E+00	0.245690E-01	-0.203877E+00	-0.194776E+00	-0.183234E+00
0.851957E+00	0.202534E-01	-0.207704E+00	-0.170468E+00	-0.160003E+00
0.872982E+00	0.158487E-01	-0.211048E+00	-0.147610E+00	-0.138270E+00
0.894064E+00	0.113666E-01	-0.214043E+00	-0.136489E+00	-0.127620E+00
0.915194E+00	0.681341E-02	-0.216632E+00	-0.108572E+00	-0.101354E+00
0.936362E+00	0.220341E-02	-0.218993E+00	-0.114520E+00	-0.106749E+00
0.957559E+00	-0.246430E-02	-0.221491E+00	-0.121186E+00	-0.112786E+00
0.978775E+00	-0.719074E-02	-0.231675E+00	-0.838878E+00	-0.775604E+00
0.100000E+01	-0.122970E-01	-0.240578E+00	0.000000E+00	0.000000E+00

Modified NACA 64412 Airfoil  
Revised lower surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	-0.124267E+02	0.000000E+00	0.000000E+00
0.225000E-03	-0.279600E-02	-0.100641E+02	0.210000E+05	0.203002E+02
0.901000E-03	-0.480100E-02	-0.247200E+01	0.146146E+04	0.770743E+02
0.202700E-02	-0.665800E-02	-0.143657E+01	0.377676E+03	0.704278E+02
0.360300E-02	-0.845300E-02	-0.100761E+01	0.166682E+03	0.582617E+02
0.562700E-02	-0.101510E-01	-0.759640E+00	0.783525E+02	0.395624E+02
0.810000E-02	-0.117900E-01	-0.605001E+00	0.467098E+02	0.292563E+02
0.110190E-01	-0.133570E-01	-0.487764E+00	0.336169E+02	0.244074E+02
0.143840E-01	-0.148080E-01	-0.396544E+00	0.206000E+02	0.165473E+02
0.181930E-01	-0.161690E-01	-0.330275E+00	0.141962E+02	0.121542E+02
0.224450E-01	-0.174450E-01	-0.283473E+00	0.781795E+01	0.696213E+01
0.271370E-01	-0.186890E-01	-0.252642E+00	0.532385E+01	0.485198E+01
0.322670E-01	-0.199150E-01	-0.228802E+00	0.397078E+01	0.367820E+01
0.378330E-01	-0.211270E-01	-0.209208E+00	0.306946E+01	0.287843E+01
0.438330E-01	-0.223270E-01	-0.192105E+00	0.263193E+01	0.249268E+01
0.502640E-01	-0.235080E-01	-0.176192E+00	0.231689E+01	0.221304E+01
0.571230E-01	-0.246620E-01	-0.161365E+00	0.200651E+01	0.193062E+01
0.644060E-01	-0.257840E-01	-0.148066E+00	0.164555E+01	0.159280E+01
0.721110E-01	-0.268760E-01	-0.136379E+00	0.138809E+01	0.135025E+01
0.802340E-01	-0.279380E-01	-0.126159E+00	0.112828E+01	0.110187E+01
0.887720E-01	-0.289741E-01	-0.117264E+00	0.955360E+00	0.935980E+00
0.977200E-01	-0.299851E-01	-0.109130E+00	0.862815E+00	0.847629E+00
0.107074E+00	-0.309681E-01	-0.102068E+00	0.647118E+00	0.637135E+00
0.116831E+00	-0.319332E-01	-0.952284E-01	0.754899E+00	0.744745E+00
0.126986E+00	-0.328613E-01	-0.884711E-01	0.575881E+00	0.569185E+00
0.137534E+00	-0.337625E-01	-0.823295E-01	0.588656E+00	0.582721E+00

PROFILE User's Guide (Appendix D, Sample 4)

0.148471E+00	-0.346277E-01	-0.762364E-01	0.525621E+00	0.521071E+00
0.159791E+00	-0.354570E-01	-0.703760E-01	0.509812E+00	0.506047E+00
0.171490E+00	-0.362455E-01	-0.647830E-01	0.446300E+00	0.443505E+00
0.183563E+00	-0.369951E-01	-0.594134E-01	0.443202E+00	0.440866E+00
0.196003E+00	-0.376999E-01	-0.541065E-01	0.410006E+00	0.408212E+00
0.208805E+00	-0.383590E-01	-0.489326E-01	0.398323E+00	0.396897E+00
0.221964E+00	-0.389684E-01	-0.437253E-01	0.393136E+00	0.392012E+00
0.235474E+00	-0.395232E-01	-0.384474E-01	0.388161E+00	0.387302E+00
0.249328E+00	-0.400186E-01	-0.331683E-01	0.373886E+00	0.373270E+00
0.263520E+00	-0.404517E-01	-0.279193E-01	0.365842E+00	0.365415E+00
0.278044E+00	-0.408186E-01	-0.226256E-01	0.363078E+00	0.362799E+00
0.292893E+00	-0.411146E-01	-0.172847E-01	0.356251E+00	0.356091E+00
0.308061E+00	-0.413357E-01	-0.120240E-01	0.337396E+00	0.337323E+00
0.323541E+00	-0.414815E-01	-0.677644E-02	0.340577E+00	0.340554E+00
0.339325E+00	-0.415460E-01	-0.109976E-02	0.378671E+00	0.378670E+00
0.355407E+00	-0.415147E-01	0.560209E-02	0.454764E+00	0.454742E+00
0.371780E+00	-0.413620E-01	0.135297E-01	0.513597E+00	0.513456E+00
0.388436E+00	-0.410654E-01	0.227419E-01	0.592573E+00	0.592113E+00
0.405367E+00	-0.405955E-01	0.327858E-01	0.593899E+00	0.592943E+00
0.422566E+00	-0.399437E-01	0.424749E-01	0.532789E+00	0.531350E+00
0.440025E+00	-0.391210E-01	0.511987E-01	0.466579E+00	0.464751E+00
0.457737E+00	-0.381409E-01	0.587282E-01	0.383634E+00	0.381658E+00
0.475693E+00	-0.370246E-01	0.650581E-01	0.321415E+00	0.319385E+00
0.493885E+00	-0.357879E-01	0.706181E-01	0.289829E+00	0.287674E+00
0.512305E+00	-0.344379E-01	0.755241E-01	0.242858E+00	0.240795E+00
0.530945E+00	-0.329879E-01	0.797712E-01	0.212856E+00	0.210841E+00
0.549796E+00	-0.314464E-01	0.833831E-01	0.170370E+00	0.168608E+00
0.568850E+00	-0.298266E-01	0.864244E-01	0.148879E+00	0.147227E+00
0.588099E+00	-0.281355E-01	0.888407E-01	0.102186E+00	0.100988E+00
0.607533E+00	-0.263897E-01	0.905642E-01	0.751730E-01	0.742575E-01
0.627144E+00	-0.245991E-01	0.916866E-01	0.392961E-01	0.388058E-01
0.646922E+00	-0.227781E-01	0.920627E-01	-0.127109E-02	-0.125510E-02
0.666860E+00	-0.209428E-01	0.917013E-01	-0.349914E-01	-0.345546E-01
0.686948E+00	-0.191077E-01	0.906894E-01	-0.657532E-01	-0.649503E-01
0.707177E+00	-0.172866E-01	0.888571E-01	-0.115407E+00	-0.114054E+00
0.727538E+00	-0.155013E-01	0.860600E-01	-0.159335E+00	-0.157581E+00
0.748022E+00	-0.137719E-01	0.822338E-01	-0.214253E+00	-0.212098E+00
0.768619E+00	-0.121236E-01	0.772573E-01	-0.268971E+00	-0.266581E+00
0.789321E+00	-0.105819E-01	0.709662E-01	-0.338802E+00	-0.336259E+00
0.810117E+00	-0.917930E-02	0.630980E-01	-0.417900E+00	-0.415417E+00
0.830999E+00	-0.795280E-02	0.535546E-01	-0.496139E+00	-0.494012E+00
0.851957E+00	-0.693937E-02	0.421224E-01	-0.594825E+00	-0.593245E+00
0.872982E+00	-0.618522E-02	0.285104E-01	-0.700013E+00	-0.699161E+00
0.894064E+00	-0.573972E-02	0.123568E-01	-0.832440E+00	-0.832250E+00
0.915194E+00	-0.566445E-02	-0.724792E-02	-0.102319E+01	-0.102311E+01
0.936362E+00	-0.604712E-02	-0.318503E-01	-0.130129E+01	-0.129931E+01
0.957559E+00	-0.701459E-02	-0.652863E-01	-0.185350E+01	-0.184171E+01
0.978775E+00	-0.881686E-02	-0.124448E+00	-0.372358E+01	-0.363873E+01
0.100000E+01	-0.122970E-01	-0.163965E+00	0.000000E+00	0.000000E+00

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PROFILE User's Guide (Appendix D, Sample 4)

Current % thickness: 12.09253  
Corresponding abscissa: 0.3717800



## PROFILE User's Guide (Appendix D, Sample 5)

### (5) Ames-01 Airfoil - Mode 5 (refine thickness/curvature)

In this example, the Ames-01 rotor section is smoothed using target second derivatives, and the thickness is refined to 10%. The target y" values were derived by hand-editing the .YPP file from a preliminary run of PROFILE on AMES01.DAT using MODE=0. The plots of curvature from this MODE=0 run guided the smoothing out of the second derivatives by hand, where some trial-and-error is suggested till the user develops a feel for cause and effect.

The resulting plots of the airfoil and curvature are shown, preceded by the .TAB file, which shows details of the iteration necessary to achieve the requested thickness ratio.

Remember that REFINE mode has an option suited to knocking out spikes in the curvature, or to flattening the curvature plots in some single range of abscissas. This does not require an input table of y" values. The option is not illustrated for reasons of space.

About 7 seconds of VAX-11/780 CPU time were used for the complete run in REFINE mode that follows.

---

#### Sample Terminal Session - Refine thickness/curvature

---

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:

- 0 = default (no modifications) - just plot and tabulate
- 1 = rectify leading edge definition
- 2 = normalize or de-normalize geometry
- 3 = redistribute the abscissas
- 4 = modify - apply shape functions
- 5 = refine thickness/curvature
- 6 = optimize one surface (bumps + target curvatures)

Enter MODE, else <CR> for MODE = 0: 5

Enter the PROFILE control file (default is PROFILE.INP):

AMES01.INP

Enter the airfoil geometry data file (default is AIRFOIL.DAT):

AMES01.DAT

Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.\*:

SAMPLES

Enter plot title (up to 80 chars.) <CR> uses PROFILE for the title:

Program PROFILE: REFINE mode used on Ames-01 Rotor Section

Enter plot subtitle (up to 80 characters) or <CR> if none:

# PROFILE User's Guide (Appendix D, Sample 5)

Curvature smoothed via target y" distribution; new T/C=10%  
Do you want an explanation of the prompts to follow? (Y/N; <CR>=No): y

REFINE works with 2N equations in N unknowns (the ys):

N of the form  $y(\text{new}) = \text{scale} * y(\text{old})$   
and N of the form  $wt * y(\text{new}) = wt * y(\text{desired})$

where wt represents weighting of the second derivative equations to equilibrate the two halves of the system.

The first half enables thickness to be changed, while the second half enables the second derivatives (and hence the curvature distribution) to be smoothed. The scaling and the weighting use "sine" shape functions which must be controlled by you the user -- hence the series of prompts to be discussed next.

<Hit RETURN for more.><CR>

Thickness ratio refinement:

The nonlinear y scaling is intended to preserve as much as possible the curvature near the leading and trailing edges. The sine function is centered at the point of maximum thickness. Higher powers of the sine tend to preserve the leading/trailing-edge properties better.

Curvature smoothing:

Typical weighting of the y" equations varies from 0.004 at the leading and trailing edges to 0.04 at the center of the region of interest (where most of the smoothing is sought). Use a power of 3. or 4. to smooth out some NARROW region of noisy curvature, else a lesser power (1., 1.5, or 2.) if BROAD smoothing is sought (probably in conjunction with a table of target 2nd derivatives).

Original % thickness: 10.27440.  
Enter desired % thickness, or <CR> to keep same: 10.0  
Enter power of sine to use for y scaling (<CR> = 2.): <CR>  
Enter file name for target 2nd derivatives; <CR> if none: AMES1TARG.YPP  
Is the upper surface to be left unchanged? (Y/N; <CR>=No): <CR>

Smoothing of upper surface is controlled by the following:  
Center of smoothed region? <CR> gives x/c=0.5: <CR>  
Power of sine for y" weights? <CR> gives 3.0: <CR>

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PROFILE User's Guide (Appendix D, Sample 5)

Weight at  $x/c=0.1$  for  $y$ ? <CR> gives .004: <CR>  
Peak weight for  $y$ ? <CR> gives .040: <CR>

Is the lower surface to be left unchanged? (Y/N; <CR>=No): <CR>

Smoothing of lower surface is controlled by the following:

Center of smoothed region? <CR> gives  $x/c=0.5$ : <CR>  
Power of sine for  $y$  weights? <CR> gives 3.0: <CR>  
Weight at  $x/c=0.1$  for  $y$ ? <CR> gives .004: <CR>  
Peak weight for  $y$ ? <CR> gives .040: <CR>

Current % thickness: 10.07905 Corresponding  $x/c$ : 0.3500000  
Current % thickness: 10.01628 Corresponding  $x/c$ : 0.3500000  
Current % thickness: 9.943483 Corresponding  $x/c$ : 0.3500000  
Current % thickness: 10.00000 Corresponding  $x/c$ : 0.3500000

Modified airfoil: SAMPLE5.DAT  
Airfoil plot file: SAMPLE5.PLT  
Tabulated results: SAMPLE5.TAB  
Curvature QPLOT file: SAMPLE5.CRV  
2nd derivatives file: SAMPLE5.YPP

---

SAMPLE5.TAB file

---

Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

Operating mode: 5  
 Control file : AMES01.INP  
 Geometry file : AMES01.DAT  
 Output file id: SAMPLE5  
 Profiles found: 1

Case: Program PROFILE: REFINE mode used on Ames-01 Rotor Section

Original thickness : 10.27440  
 Corresponding x/c : 0.3000000  
 Desired thickness : 10.00000  
 y-scaling sine power: 2.000000  
 Table of y" values used: AMES1TARG.YPP  
 Values of y" found in table follow:

ORIGINAL AMES 01

39 Upper surface
0.000200 -2.90E+04
0.000500 -3.39E+03
0.001000 -1.39E+03
0.002000 -4.73E+02
0.003500 -2.07E+02
0.005000 -1.23E+02
0.006500 -7.91E+01
0.008000 -5.53E+01
0.010000 -3.90E+01
0.012500 -2.82E+01
0.016000 -2.05E+01
0.020000 -1.56E+01
0.025000 -1.15E+01
0.035000 -7.800028
0.050000 -5.457758
0.065000 -4.222221
0.080000 -3.500000
0.100000 -2.600000
0.125000 -1.800000
0.150000 -1.300000
0.200000 -0.650000
0.250000 -0.350000
0.300000 -0.260000
0.350000 -0.250000
0.400000 -0.260000
0.450000 -0.270000

PROFILE User's Guide (Appendix D, Sample 5)

0.500000 -0.278400  
 0.550000 -0.297999  
 0.600000 -0.326000  
 0.650000 -0.359998  
 0.700000 -0.397999  
 0.750000 -0.375999  
 0.800000 -0.226402  
 0.850000 -0.032005  
 0.900000 0.443743  
 0.925000 0.900000  
 0.950000 1.300000  
 0.975000 1.700000  
 0.990000 1.973337  
 39 Lower Surface  
 0.000200 2.93E+04  
 0.000500 2.84E+03  
 0.001000 1.19E+03  
 0.002000 4.08E+02  
 0.003500 1.84E+02  
 0.005000 1.15E+02  
 0.006500 7.87E+01  
 0.008000 5.69E+01  
 0.010000 4.08E+01  
 0.012500 2.96E+01  
 0.016000 2.10E+01  
 0.020000 1.48E+01  
 0.025000 1.02E+01  
 0.035000 4.954659  
 0.050000 2.022221  
 0.065000 0.964428  
 0.080000 0.680957  
 0.100000 0.580000  
 0.125000 0.468794  
 0.150000 0.384002  
 0.200000 0.340000  
 0.250000 0.302399  
 0.300000 0.255601  
 0.350000 0.218401  
 0.400000 0.194800  
 0.450000 0.190000  
 0.500000 0.187601  
 0.550000 0.164000  
 0.600000 0.143602  
 0.650000 0.120398  
 0.700000 0.114000  
 0.750000 0.132000  
 0.800000 0.141600  
 0.850000 0.176402  
 0.900000 0.260000

# PROFILE User's Guide (Appendix D, Sample 5)

0.925000 0.300000  
0.950000 0.330000  
0.975000 0.300000  
0.990000 0.260000

Controls for upper surface follow:

x/c at peak y" weight : 0.500000  
Sine power for y" weights: 3.000000  
y" weight at x/c=0 and 1 : 4.000000E-03  
Peak y" weight : 3.999999E-02

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.99999	0.0005	0.99996	0.0010	0.99991	0.0020	0.99979
0.0035	0.99961	0.0050	0.99941	0.0065	0.99921	0.0080	0.99900	0.0100	0.99871
0.0125	0.99834	0.0160	0.99781	0.0200	0.99719	0.0250	0.99640	0.0350	0.99482
0.0500	0.99247	0.0650	0.99019	0.0800	0.98802	0.1000	0.98534	0.1250	0.98236
0.1500	0.97981	0.2000	0.97605	0.2500	0.97394	0.3000	0.97329	0.3500	0.97386
0.4000	0.97537	0.4500	0.97760	0.5000	0.98028	0.5500	0.98323	0.6000	0.98624
0.6500	0.98918	0.7000	0.99190	0.7500	0.99432	0.8000	0.99635	0.8500	0.99795
0.9000	0.99910	0.9250	0.99950	0.9500	0.99978	0.9750	0.99994	0.9900	0.99999
1.0000	1.00000								

Weights used for y" at each upper surface x/c:

0.0000	0.00400	0.0002	0.00400	0.0005	0.00400	0.0010	0.00400	0.0020	0.00400
0.0035	0.00400	0.0050	0.00400	0.0065	0.00400	0.0080	0.00400	0.0100	0.00400
0.0125	0.00400	0.0160	0.00400	0.0200	0.00401	0.0250	0.00402	0.0350	0.00405
0.0500	0.00414	0.0650	0.00430	0.0800	0.00455	0.1000	0.00506	0.1250	0.00602
0.1500	0.00737	0.2000	0.01131	0.2500	0.01673	0.3000	0.02306	0.3500	0.02947
0.4000	0.03497	0.4500	0.03869	0.5000	0.04000	0.5500	0.03869	0.6000	0.03497
0.6500	0.02947	0.7000	0.02306	0.7500	0.01673	0.8000	0.01131	0.8500	0.00737
0.9000	0.00506	0.9250	0.00446	0.9500	0.00414	0.9750	0.00402	0.9900	0.00400
1.0000	0.00400								

RHS vector, of length 2N, where N = NSRF-2 =

39:

2.3790E-03	3.7708E-03	5.4135E-03	7.6544E-03	1.0129E-02	1.2137E-02	1.3867E-02	1.5419E-02	1.7293E-02	1.9415E-02
2.2087E-02	2.4831E-02	2.7905E-02	3.3178E-02	3.9605E-02	4.4789E-02	4.9016E-02	5.3415E-02	5.7259E-02	5.9746E-02
6.1916E-02	6.2634E-02	6.2739E-02	6.2413E-02	6.1601E-02	6.0165E-02	5.8069E-02	5.5291E-02	5.1764E-02	4.7404E-02
4.2116E-02	3.5797E-02	2.8500E-02	2.0598E-02	1.2585E-02	8.9855E-03	5.9777E-03	3.9188E-03	3.2160E-03	
-1.1600E+02	-1.3560E+01	-5.5600E+00	-1.8920E+00	-8.2801E-01	-4.9202E-01	-3.1642E-01	-2.2123E-01	-1.5604E-01	-1.1286E-01
-8.2094E-02	-6.2539E-02	-4.6200E-02	-3.1571E-02	-2.2583E-02	-1.8156E-02	-1.5938E-02	-1.3162E-02	-1.0832E-02	-9.5791E-03
-7.3519E-03	-5.8548E-03	-5.9962E-03	-7.3663E-03	-9.0918E-03	-1.0445E-02	-1.1136E-02	-1.1529E-02	-1.1400E-02	-1.0607E-02
-9.1788E-03	-6.2897E-03	-2.5608E-03	-2.3583E-04	2.2464E-03	4.0122E-03	5.3792E-03	6.8296E-03	8.7939E-02	

Sum of squares obtained: 5.5919186E-06

# PROFILE User's Guide (Appendix D, Sample 5)

Controls for lower surface follow:

x/c at peak y" weight : 0.5000000  
 Sine power for y" weights: 3.000000  
 y" weight at x/c=0 and 1 : 4.0000002E-03  
 Peak y" weight : 3.9999999E-02

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.99999	0.0005	0.99996	0.0010	0.99991	0.0020	0.99979
0.0035	0.99961	0.0050	0.99941	0.0065	0.99921	0.0080	0.99900	0.0100	0.99871
0.0125	0.99834	0.0160	0.99781	0.0200	0.99719	0.0250	0.99640	0.0350	0.99482
0.0500	0.99247	0.0650	0.99019	0.0800	0.98802	0.1000	0.98534	0.1250	0.98236
0.1500	0.97981	0.2000	0.97605	0.2500	0.97394	0.3000	0.97329	0.3500	0.97386
0.4000	0.97537	0.4500	0.97760	0.5000	0.98028	0.5500	0.98323	0.6000	0.98624
0.6500	0.98918	0.7000	0.99190	0.7500	0.99432	0.8000	0.99635	0.8500	0.99795
0.9000	0.99910	0.9250	0.99950	0.9500	0.99978	0.9750	0.99994	0.9900	0.99999
1.0000	1.00000								

Weights used for y" at each lower surface x/c:

0.0000	0.00400	0.0002	0.00400	0.0005	0.00400	0.0010	0.00400	0.0020	0.00400
0.0035	0.00400	0.0050	0.00400	0.0065	0.00400	0.0080	0.00400	0.0100	0.00400
0.0125	0.00400	0.0160	0.00400	0.0200	0.00401	0.0250	0.00402	0.0350	0.00405
0.0500	0.00414	0.0650	0.00430	0.0800	0.00455	0.1000	0.00506	0.1250	0.00602
0.1500	0.00737	0.2000	0.01131	0.2500	0.01673	0.3000	0.02306	0.3500	0.02947
0.4000	0.03497	0.4500	0.03869	0.5000	0.04000	0.5500	0.03869	0.6000	0.03497
0.6500	0.02947	0.7000	0.02306	0.7500	0.01673	0.8000	0.01131	0.8500	0.00737
0.9000	0.00506	0.9250	0.00446	0.9500	0.00414	0.9750	0.00402	0.9900	0.00400
1.0000	0.00400								

RHS vector, of length 2N, where N = NSRF-2 = 39:

-2.2280E-03	-3.3749E-03	-4.7186E-03	-6.5107E-03	-8.4327E-03	-9.9392E-03	-1.1187E-02	-1.2258E-02	-1.3486E-02	-1.4790E-02
-1.6308E-02	-1.7720E-02	-1.9154E-02	-2.1256E-02	-2.3476E-02	-2.5236E-02	-2.6776E-02	-2.8591E-02	-3.0490E-02	-3.2106E-02
-3.4655E-02	-3.6301E-02	-3.7261E-02	-3.7644E-02	-3.7533E-02	-3.6973E-02	-3.5928E-02	-3.4426E-02	-3.2512E-02	-3.0227E-02
-2.7624E-02	-2.4716E-02	-2.1455E-02	-1.7820E-02	-1.3727E-02	-1.1429E-02	-8.8790E-03	-6.0267E-03	-4.2060E-03	1.1846E-01
1.1720E+02	1.1360E+01	4.7600E+00	1.6320E+00	7.3601E-01	4.6002E-01	3.1482E-01	2.2763E-01	1.6325E-01	2.8295E-03
8.4096E-02	5.9332E-02	4.0977E-02	2.0054E-02	8.3676E-03	4.1472E-03	3.1009E-03	2.9361E-03	2.8210E-03	5.0216E-03
3.8456E-03	5.0585E-03	5.8947E-03	6.4352E-03	6.8119E-03	7.3505E-03	7.5040E-03	6.3446E-03	5.0216E-03	3.5475E-03
2.6291E-03	2.2081E-03	1.6016E-03	1.2998E-03	1.3162E-03	1.3374E-03	1.3655E-03	1.2052E-03	9.7195E-02	

Sum of squares obtained: 1.3632679E-06

Current % thickness: 10.07905  
 Corresponding abscissa: 0.3500000

# PROFILE User's Guide (Appendix D, Sample 5)

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.99998	0.0005	0.99995	0.0010	0.99988	0.0020	0.99974
0.0035	0.99950	0.0050	0.99924	0.0065	0.99898	0.0080	0.99871	0.0100	0.99834
0.0125	0.99786	0.0160	0.99718	0.0200	0.99638	0.0250	0.99537	0.0350	0.99333
0.0500	0.99030	0.0650	0.98736	0.0800	0.98457	0.1000	0.98111	0.1250	0.97727
0.1500	0.97400	0.2000	0.96915	0.2500	0.96643	0.3000	0.96560	0.3500	0.96632
0.4000	0.96828	0.4500	0.97114	0.5000	0.97460	0.5500	0.97840	0.6000	0.98228
0.6500	0.98606	0.7000	0.98957	0.7500	0.99268	0.8000	0.99530	0.8500	0.99736
0.9000	0.99884	0.9250	0.99935	0.9500	0.99971	0.9750	0.99993	0.9900	0.99999
1.0000	1.00000								

RHS vector, of length 2N, where N = NSRF-2 =

39:

2.3790E-03	3.7708E-03	5.4134E-03	7.6540E-03	1.0128E-02	1.2135E-02	1.3864E-02	1.5414E-02	1.7286E-02	1.9405E-02
2.2073E-02	2.4811E-02	2.7876E-02	3.3129E-02	3.9519E-02	4.4661E-02	4.8044E-02	5.3186E-02	5.6962E-02	5.9392E-02
6.1478E-02	6.2151E-02	6.2243E-02	6.1931E-02	6.1153E-02	5.9768E-02	5.7733E-02	5.5019E-02	5.1556E-02	4.7255E-02
4.2017E-02	3.5738E-02	2.8469E-02	2.0586E-02	1.2581E-02	8.9842E-03	5.9773E-03	3.9187E-03	3.2160E-03	
-1.1600E+02	-1.3560E+01	-5.5600E+00	-1.8920E+00	-8.2801E-01	-4.9202E-01	-3.1642E-01	-2.2123E-01	-1.5604E-01	-1.1286E-01
-8.2094E-02	-6.2539E-02	-4.6200E-02	-3.1571E-02	-2.2583E-02	-1.8156E-02	-1.5938E-02	-1.3162E-02	-1.0832E-02	-9.5791E-03
-7.3519E-03	-5.8548E-03	-5.9962E-03	-7.3663E-03	-9.0918E-03	-1.0445E-02	-1.1136E-02	-1.1529E-02	-1.1400E-02	-1.0607E-02
-9.1788E-03	-6.2897E-03	-2.5608E-03	-2.3583E-04	2.2464E-03	4.0122E-03	5.3792E-03	6.8296E-03	8.7939E-02	

Sum of squares obtained: 6.4313249E-06

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.99998	0.0005	0.99995	0.0010	0.99988	0.0020	0.99974
0.0035	0.99950	0.0050	0.99924	0.0065	0.99898	0.0080	0.99871	0.0100	0.99834
0.0125	0.99786	0.0160	0.99718	0.0200	0.99638	0.0250	0.99537	0.0350	0.99333
0.0500	0.99030	0.0650	0.98736	0.0800	0.98457	0.1000	0.98111	0.1250	0.97727
0.1500	0.97400	0.2000	0.96915	0.2500	0.96643	0.3000	0.96560	0.3500	0.96632
0.4000	0.96828	0.4500	0.97114	0.5000	0.97460	0.5500	0.97840	0.6000	0.98228
0.6500	0.98606	0.7000	0.98957	0.7500	0.99268	0.8000	0.99530	0.8500	0.99736
0.9000	0.99884	0.9250	0.99935	0.9500	0.99971	0.9750	0.99993	0.9900	0.99999
1.0000	1.00000								

RHS vector, of length 2N, where N = NSRF-2 =

39:

-2.2280E-03	-3.3748E-03	-4.7184E-03	-6.5103E-03	-8.4318E-03	-9.9375E-03	-1.1185E-02	-1.2254E-02	-1.3481E-02	-1.4783E-02
-1.6295E-02	-1.7706E-02	-1.9134E-02	-2.1224E-02	-2.3424E-02	-2.5164E-02	-2.6683E-02	-2.8468E-02	-3.0333E-02	-3.1915E-02
-3.4410E-02	-3.6021E-02	-3.6966E-02	-3.7353E-02	-3.7260E-02	-3.6729E-02	-3.5720E-02	-3.4257E-02	-3.2381E-02	-3.0132E-02
-2.7559E-02	-2.4675E-02	-2.1433E-02	-1.7810E-02	-1.3723E-02	-1.1428E-02	-8.8785E-03	-6.0266E-03	-4.2060E-03	
1.1720E+02	1.1360E+01	4.7600E+00	1.6320E+00	7.3601E-01	4.6002E-01	3.1482E-01	2.2763E-01	1.6325E-01	1.1846E-01
8.4096E-02	5.9332E-02	4.0977E-02	2.0054E-02	8.3676E-03	4.1472E-03	3.1009E-03	2.9361E-03	2.8210E-03	2.8295E-03
3.8456E-03	5.0585E-03	5.8947E-03	6.4352E-03	6.8119E-03	7.3505E-03	7.5040E-03	6.3446E-03	5.0216E-03	3.5475E-03
2.6291E-03	2.2081E-03	1.6016E-03	1.2998E-03	1.3162E-03	1.3374E-03	1.3655E-03	1.2052E-03	9.7195E-02	



PROFILE User's Guide (Appendix D, Sample 5)

Sum of squares obtained: 1.6706110E-06

Current % thickness: 10.01628  
Corresponding abscissa: 0.3500000

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.9998	0.0005	0.9993	0.0010	0.9985	0.0020	0.9967
0.0035	0.99937	0.0050	0.99905	0.0065	0.99872	0.0080	0.99837	0.0100	0.99791
0.0125	0.99731	0.0160	0.99644	0.0200	0.99544	0.0250	0.99417	0.0350	0.99160
0.0500	0.98778	0.0650	0.98408	0.0800	0.98056	0.1000	0.97621	0.1250	0.97138
0.1500	0.96725	0.2000	0.96114	0.2500	0.95773	0.3000	0.95667	0.3500	0.95759
0.4000	0.96005	0.4500	0.96365	0.5000	0.96801	0.5500	0.97279	0.6000	0.97768
0.6500	0.98244	0.7000	0.98686	0.7500	0.99078	0.8000	0.99408	0.8500	0.99668
0.9000	0.99854	0.9250	0.99918	0.9500	0.99964	0.9750	0.99991	0.9900	0.99999
1.0000	1.00000								

RHS vector, of length 2N, where N = NSRF-2 = 39:

2.3789E-03	3.7707E-03	5.4132E-03	7.6535E-03	1.0127E-02	1.2132E-02	1.3860E-02	1.5409E-02	1.7279E-02	1.9395E-02
2.2057E-02	2.4787E-02	2.7843E-02	3.3071E-02	3.9418E-02	4.4513E-02	4.8646E-02	5.2920E-02	5.6619E-02	5.8980E-02
6.0970E-02	6.1591E-02	6.1668E-02	6.1371E-02	6.0633E-02	5.9307E-02	5.7342E-02	5.4704E-02	5.1315E-02	4.7082E-02
4.1902E-02	3.5670E-02	2.8435E-02	2.0571E-02	1.2578E-02	8.9826E-03	5.9768E-03	3.9186E-03	3.2160E-03	
-1.1600E+02	-1.3560E+01	-5.5600E+00	-1.8920E+00	-8.2801E-01	-4.9202E-01	-3.1642E-01	-2.2123E-01	-1.5604E-01	-1.1286E-01
-8.2094E-02	-6.2539E-02	-4.6200E-02	-3.1571E-02	-2.2583E-02	-1.8156E-02	-1.5938E-02	-1.3162E-02	-1.0832E-02	-9.5791E-03
-7.3519E-03	-5.8548E-03	-5.9962E-03	-7.3663E-03	-9.0918E-03	-1.0445E-02	-1.1136E-02	-1.1529E-02	-1.1400E-02	-1.0607E-02
-9.1788E-03	-6.2897E-03	-2.5608E-03	-2.3583E-04	2.2464E-03	4.0122E-03	5.3792E-03	6.8296E-03	-8.7939E-02	

Sum of squares obtained: 7.8194034E-06

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.9998	0.0005	0.9993	0.0010	0.9985	0.0020	0.9967
0.0035	0.99937	0.0050	0.99905	0.0065	0.99872	0.0080	0.99837	0.0100	0.99791
0.0125	0.99731	0.0160	0.99644	0.0200	0.99544	0.0250	0.99417	0.0350	0.99160
0.0500	0.98778	0.0650	0.98408	0.0800	0.98056	0.1000	0.97621	0.1250	0.97138
0.1500	0.96725	0.2000	0.96114	0.2500	0.95773	0.3000	0.95667	0.3500	0.95759
0.4000	0.96005	0.4500	0.96365	0.5000	0.96801	0.5500	0.97279	0.6000	0.97768
0.6500	0.98244	0.7000	0.98686	0.7500	0.99078	0.8000	0.99408	0.8500	0.99668
0.9000	0.99854	0.9250	0.99918	0.9500	0.99964	0.9750	0.99991	0.9900	0.99999
1.0000	1.00000								

RHS vector, of length 2N, where N = NSRF-2 = 39:

-2.2279E-03	-3.3748E-03	-4.7183E-03	-6.5098E-03	-8.4307E-03	-9.9355E-03	-1.1182E-02	-1.2250E-02	-1.3475E-02	-1.4775E-02
-1.6283E-02	-1.7689E-02	-1.9111E-02	-2.1187E-02	-2.3365E-02	-2.5080E-02	-2.6574E-02	-2.8326E-02	-3.0150E-02	-3.1694E-02

# PROFILE User's Guide (Appendix D, Sample 5)

-3.4125E-02	-3.5696E-02	-3.6624E-02	-3.7016E-02	-3.6944E-02	-3.6445E-02	-3.5479E-02	-3.4060E-02	-3.2229E-02	-3.0022E-02
-2.7484E-02	-2.4628E-02	-2.1406E-02	-1.7798E-02	-1.3719E-02	-1.1426E-02	-8.8778E-03	-6.0285E-03	-4.2059E-03	1.1846E-01
1.1720E+02	1.1360E+01	4.7600E+00	1.6320E+00	7.3601E-01	4.6002E-01	3.1482E-01	2.2763E-01	1.6325E-01	2.8295E-03
8.4098E-02	5.9332E-02	4.0977E-02	2.0054E-02	8.3676E-03	4.1472E-03	3.1099E-03	2.9361E-03	2.8210E-03	3.5475E-03
3.8456E-03	5.0585E-03	5.8947E-03	6.4352E-03	6.8119E-03	7.3505E-03	7.5040E-03	6.3446E-03	5.0216E-03	
2.6291E-03	2.2081E-03	1.6016E-03	1.2998E-03	1.3162E-03	1.3374E-03	1.3655E-03	1.2052E-03	9.7195E-02	

Sum of squares obtained: 2.1727867E-06

Current % thickness: 9.943483  
Corresponding abscissa: 0.3500000

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.9998	0.0005	0.9994	0.0010	0.9997	0.0020	0.99972
0.0035	0.99947	0.0050	0.99920	0.0065	0.99892	0.0080	0.99863	0.0100	0.99824
0.0125	0.99774	0.0160	0.99701	0.0200	0.99617	0.0250	0.99510	0.0350	0.99294
0.0500	0.98973	0.0650	0.98663	0.0800	0.98367	0.1000	0.98002	0.1250	0.97596
0.1500	0.97249	0.2000	0.96736	0.2500	0.96449	0.3000	0.96360	0.3500	0.96437
0.4000	0.96644	0.4500	0.96947	0.5000	0.97313	0.5500	0.97714	0.6000	0.98125
0.6500	0.98525	0.7000	0.98896	0.7500	0.99225	0.8000	0.99502	0.8500	0.99721
0.9000	0.99877	0.9250	0.99931	0.9500	0.99970	0.9750	0.99992	0.9900	0.99999
1.0000	1.00000								

RHS vector, of length 2N, where N = NSRF-2 = 39:

2.3790E-03	3.7708E-03	5.4133E-03	7.6539E-03	1.0128E-02	1.2134E-02	1.3863E-02	1.5413E-02	1.7285E-02	1.9403E-02
2.2070E-02	2.4806E-02	2.7869E-02	3.3116E-02	3.9496E-02	4.4628E-02	4.8800E-02	5.3127E-02	5.6885E-02	5.9300E-02
6.1364E-02	6.2026E-02	6.2115E-02	6.1806E-02	6.1036E-02	5.9665E-02	5.7645E-02	5.4949E-02	5.1502E-02	4.7216E-02
4.1931E-02	3.5723E-02	2.8462E-02	2.0582E-02	1.2581E-02	8.9838E-03	5.9772E-03	3.9187E-03	3.2160E-03	
-1.1600E+02	-1.3560E+01	-5.5600E+00	-1.8920E+00	-8.2801E-01	-4.9202E-01	-3.1642E-01	-2.2123E-01	-1.5604E-01	-1.1286E-01
-8.2094E-02	-6.2539E-02	-4.6200E-02	-3.1571E-02	-2.2583E-02	-1.8156E-02	-1.5938E-02	-1.3162E-02	-1.0832E-02	-9.5791E-03
-7.3519E-03	-5.8548E-03	-5.9962E-03	-7.3663E-03	-9.0918E-03	-1.0445E-02	-1.1136E-02	-1.1529E-02	-1.1400E-02	-1.0607E-02
-9.1788E-03	-6.2897E-03	-2.5608E-03	-2.3583E-04	2.2464E-03	4.0122E-03	5.3792E-03	6.8296E-03	-8.7939E-02	

Sum of squares obtained: 6.7034102E-06

y scale factors sought at each x:

0.0000	1.00000	0.0002	0.99998	0.0005	0.99994	0.0010	0.99987	0.0020	0.99972
0.0035	0.99947	0.0050	0.99920	0.0065	0.99892	0.0080	0.99863	0.0100	0.99824
0.0125	0.99774	0.0160	0.99701	0.0200	0.99617	0.0250	0.99510	0.0350	0.99294
0.0500	0.98973	0.0650	0.98663	0.0800	0.98367	0.1000	0.98002	0.1250	0.97596
0.1500	0.97249	0.2000	0.96736	0.2500	0.96449	0.3000	0.96360	0.3500	0.96437
0.4000	0.96644	0.4500	0.96947	0.5000	0.97313	0.5500	0.97714	0.6000	0.98125

# PROFILE User's Guide (Appendix D, Sample 5)

0.6500	0.98525	0.7000	0.98896	0.7500	0.99225	0.8000	0.99502	0.8500	0.99721
0.9000	0.99877	0.9250	0.99931	0.9500	0.99970	0.9750	0.99992	0.9900	0.99999
1.0000	1.00000								
RHS vector, of length 2N, where N = NSRF-2 = 39:									
-2.2280E-03	-3.3748E-03	-4.7184E-03	-6.5102E-03	-8.4315E-03	-9.9371E-03	-1.1184E-02	-1.2253E-02	-1.3479E-02	-1.4781E-02
-1.6292E-02	-1.7702E-02	-1.9129E-02	-2.1216E-02	-2.3411E-02	-2.5145E-02	-2.6658E-02	-2.8436E-02	-3.0292E-02	-3.1866E-02
-3.4346E-02	-3.5948E-02	-3.6890E-02	-3.7278E-02	-3.7190E-02	-3.6665E-02	-3.5666E-02	-3.4213E-02	-3.2347E-02	-3.0107E-02
-2.7543E-02	-2.4664E-02	-2.1427E-02	-1.7807E-02	-1.3722E-02	-1.1427E-02	-8.8783E-03	-6.0265E-03	-4.2059E-03	
1.1720E-02	1.1360E+01	4.7600E+00	1.6320E+00	7.3601E-01	4.6002E-01	3.1482E-01	2.2763E-01	1.6325E-01	1.1846E-01
8.4096E-02	5.9332E-02	4.0977E-02	2.0054E-02	8.3676E-03	4.1472E-03	3.1009E-03	2.9361E-03	2.8210E-03	2.8295E-03
3.8456E-03	5.0585E-03	5.8947E-03	6.4352E-03	6.8119E-03	7.3505E-03	7.5040E-03	6.3446E-03	5.0216E-03	3.5475E-03
2.6291E-03	2.2081E-03	1.6016E-03	1.2998E-03	1.3162E-03	1.3374E-03	1.3655E-03	1.2052E-03	9.7195E-02	

Sum of squares obtained: 1.7694108E-06

Current % thickness: 10.00000  
Corresponding abscissa: 0.3500000

# PROFILE User's Guide (Appendix D, Sample 5)

ORIGINAL AMES 01

Original upper surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	0.118950E+02	0.000000E+00	0.000000E+00
0.200000E-03	0.237900E-02	0.899300E+01	-0.290200E+05	-0.391722E+02
0.500000E-03	0.377100E-02	0.413225E+01	-0.338500E+04	-0.440478E+02
0.100000E-02	0.541400E-02	0.293800E+01	-0.139200E+04	-0.465666E+02
0.200000E-02	0.765600E-02	0.200573E+01	-0.472534E+03	-0.419752E+02
0.350000E-02	0.101330E-01	0.149600E+01	-0.207111E+03	-0.355455E+02
0.500000E-02	0.121440E-01	0.124833E+01	-0.123111E+03	-0.300858E+02
0.650000E-02	0.138780E-01	0.109667E+01	-0.791112E+02	-0.241998E+02
0.800000E-02	0.154340E-01	0.995833E+00	-0.553330E+02	-0.196858E+02
0.100000E-01	0.173150E-01	0.901523E+00	-0.389778E+02	-0.159703E+02
0.125000E-01	0.194470E-01	0.817586E+00	-0.281715E+02	-0.130720E+02
0.160000E-01	0.221360E-01	0.732336E+00	-0.205429E+02	-0.107880E+02
0.200000E-01	0.249010E-01	0.660028E+00	-0.156112E+02	-0.907548E+01
0.250000E-01	0.280600E-01	0.592167E+00	-0.115333E+02	-0.734738E+01
0.350000E-01	0.333510E-01	0.495500E+00	-0.78003E+01	-0.561138E+01
0.500000E-01	0.399060E-01	0.396067E+00	-0.545776E+01	-0.438620E+01
0.650000E-01	0.452330E-01	0.323467E+00	-0.422222E+01	-0.363676E+01
0.800000E-01	0.496100E-01	0.265314E+00	-0.353144E+01	-0.318888E+01
0.100000E+00	0.542100E-01	0.200258E+00	-0.297421E+01	-0.280386E+01
0.125000E+00	0.582870E-01	0.135340E+00	-0.221920E+01	-0.215959E+01
0.150000E+00	0.609770E-01	0.881200E-01	-0.155840E+01	-0.154043E+01
0.200000E+00	0.634350E-01	0.333299E-01	-0.633203E+00	-0.632149E+00
0.250000E+00	0.643100E-01	0.102600E-01	-0.289597E+00	-0.289551E+00
0.300000E+00	0.644610E-01	-0.221003E-02	-0.209203E+00	-0.209201E+00
0.350000E+00	0.640890E-01	-0.130499E-01	-0.224398E+00	-0.224341E+00
0.400000E+00	0.631560E-01	-0.254500E-01	-0.271600E+00	-0.271336E+00
0.450000E+00	0.615440E-01	-0.391899E-01	-0.278002E+00	-0.277362E+00
0.500000E+00	0.592370E-01	-0.531000E-01	-0.278400E+00	-0.277227E+00
0.550000E+00	0.562340E-01	-0.675100E-01	-0.297999E+00	-0.295973E+00
0.600000E+00	0.524860E-01	-0.831101E-01	-0.326000E+00	-0.322652E+00
0.650000E+00	0.479230E-01	-0.100260E+00	-0.359998E+00	-0.354637E+00
0.700000E+00	0.424600E-01	-0.119210E+00	-0.397999E+00	-0.389663E+00
0.750000E+00	0.360020E-01	-0.138560E+00	-0.375999E+00	-0.365425E+00
0.800000E+00	0.286040E-01	-0.153620E+00	-0.226402E+00	-0.218617E+00
0.850000E+00	0.206400E-01	-0.160080E+00	-0.320049E-01	-0.308130E-01
0.900000E+00	0.125960E-01	-0.149787E+00	0.443743E+00	0.429217E+00
0.925000E+00	0.899000E-02	-0.132340E+00	0.951987E+00	0.927514E+00
0.950000E+00	0.597900E-02	-0.101420E+00	0.152161E+01	0.149843E+01
0.975000E+00	0.391900E-02	-0.601916E-01	0.177666E+01	0.176705E+01
0.990000E+00	0.321600E-02	-0.320667E-01	0.197334E+01	0.197030E+01
0.100000E+01	0.299400E-02	-0.222000E-01	0.000000E+00	0.000000E+00

# PROFILE User's Guide (Appendix D, Sample 5)

ORIGINAL AMES 01

Original lower surface

X	Y	Y'	Y''	CURVATURE
0.00000E+00	0.00000E+00	-0.111400E+02	0.00000E+00	0.00000E+00
0.20000E-03	-0.222800E-02	-0.821334E+01	0.292667E+05	0.516888E+02
0.50000E-03	-0.337500E-02	-0.339758E+01	0.283833E+04	0.638899E+02
0.10000E-02	-0.471900E-02	-0.238967E+01	0.119333E+04	0.686481E+02
0.20000E-02	-0.651200E-02	-0.158887E+01	0.408268E+03	0.617020E+02
0.35000E-02	-0.843600E-02	-0.114433E+01	0.184444E+03	0.525520E+02
0.50000E-02	-0.994500E-02	-0.920000E+00	0.114667E+03	0.457035E+02
0.65000E-02	-0.111960E-01	-0.775000E+00	0.786665E+02	0.388468E+02
0.80000E-02	-0.122700E-01	-0.673357E+00	0.568568E+02	0.324489E+02
0.10000E-01	-0.135030E-01	-0.575744E+00	0.407557E+02	0.265269E+02
0.12500E-01	-0.148150E-01	-0.487800E+00	0.295997E+02	0.214898E+02
0.16000E-01	-0.163410E-01	-0.399250E+00	0.210001E+02	0.168217E+02
0.20000E-01	-0.177700E-01	-0.327628E+00	0.148110E+02	0.127105E+02
0.25000E-01	-0.192230E-01	-0.265200E+00	0.101600E+02	0.917527E+01
0.35000E-01	-0.213670E-01	-0.189627E+00	0.495466E+01	0.469895E+01
0.50000E-01	-0.236540E-01	-0.137300E+00	0.202222E+01	0.196636E+01
0.65000E-01	-0.254860E-01	-0.114900E+00	0.964428E+00	0.945640E+00
0.80000E-01	-0.271010E-01	-0.102560E+00	0.680957E+00	0.670353E+00
0.10000E+00	-0.290160E-01	-0.891411E-01	0.660887E+00	0.653087E+00
0.12500E+00	-0.310380E-01	-0.750201E-01	0.468794E+00	0.464864E+00
0.15000E+00	-0.327670E-01	-0.643600E-01	0.384002E+00	0.381628E+00
0.20000E+00	-0.355050E-01	-0.450500E-01	0.308401E+00	0.387221E+00
0.25000E+00	-0.372720E-01	-0.277800E-01	0.302399E+00	0.302049E+00
0.30000E+00	-0.382830E-01	-0.138300E-01	0.255601E+00	0.255527E+00
0.35000E+00	-0.386550E-01	-0.198002E-02	0.218401E+00	0.218399E+00
0.40000E+00	-0.384810E-01	0.835004E-02	0.194800E+00	0.194780E+00
0.45000E+00	-0.378200E-01	0.183000E-01	0.203199E+00	0.203097E+00
0.50000E+00	-0.366510E-01	0.280700E-01	0.187601E+00	0.187379E+00
0.55000E+00	-0.350130E-01	0.368600E-01	0.164000E+00	0.163667E+00
0.60000E+00	-0.329650E-01	0.44501E-01	0.143602E+00	0.143175E+00
0.65000E+00	-0.305580E-01	0.511500E-01	0.120398E+00	0.119927E+00
0.70000E+00	-0.278500E-01	0.570100E-01	0.114000E+00	0.113447E+00
0.75000E+00	-0.248570E-01	0.631600E-01	0.132000E+00	0.131214E+00
0.80000E+00	-0.215340E-01	0.700000E-01	0.141600E+00	0.140566E+00
0.85000E+00	-0.178570E-01	0.779500E-01	0.176402E+00	0.174806E+00
0.90000E+00	-0.137390E-01	0.888933E-01	0.261328E+00	0.258261E+00
0.925000E+00	-0.114350E-01	0.971600E-01	0.400011E+00	0.394413E+00
0.950000E+00	-0.888100E-02	0.108160E+00	0.479989E+00	0.471688E+00
0.975000E+00	-0.602700E-02	0.118685E+00	0.362014E+00	0.354498E+00
0.990000E+00	-0.420600E-02	0.120680E+00	-0.960022E-01	-0.939425E-01
0.100000E+01	-0.300400E-02	0.120200E+00	0.000000E+00	0.000000E+00

# PROFILE User's Guide (Appendix D, Sample 5)

Program PROFILE: REFINE mode used on Ames-01 Rotor Section

Revised upper surface

X	Y	Y'	Y''	CURVATURE
0.00000E+00	0.00000E+00	0.118750E+02	0.00000E+00	0.00000E+00
0.20000E-03	0.23749E-02	0.897497E+01	-0.29000E+05	-0.393787E+02
0.50000E-03	0.376249E-02	0.411647E+01	-0.339001E+04	-0.445937E+02
0.10000E-02	0.539697E-02	0.292147E+01	-0.139000E+04	-0.472100E+02
0.20000E-02	0.762344E-02	0.198997E+01	-0.473001E+03	-0.428195E+02
0.35000E-02	0.100763E-01	0.147997E+01	-0.207002E+03	-0.363266E+02
0.50000E-02	0.120634E-01	0.123247E+01	-0.123002E+03	-0.307663E+02
0.65000E-02	0.137737E-01	0.108089E+01	-0.791026E+02	-0.247745E+02
0.80000E-02	0.153060E-01	0.980087E+00	-0.553014E+02	-0.201448E+02
0.10000E-01	0.171556E-01	0.885782E+00	-0.390043E+02	-0.163606E+02
0.12500E-01	0.192482E-01	0.801769E+00	-0.282062E+02	-0.133953E+02
0.16000E-01	0.218816E-01	0.716517E+00	-0.205099E+02	-0.110163E+02
0.20000E-01	0.245836E-01	0.644270E+00	-0.156140E+02	-0.927556E+01
0.25000E-01	0.276098E-01	0.576419E+00	-0.115265E+02	-0.749575E+01
0.35000E-01	0.327976E-01	0.479509E+00	-0.78557E+01	-0.452742E+01
0.50000E-01	0.391065E-01	0.379060E+00	-0.553747E+01	-0.376744E+01
0.65000E-01	0.441694E-01	0.305234E+00	-0.430602E+01	-0.328878E+01
0.80000E-01	0.482635E-01	0.246001E+00	-0.359179E+01	-0.256246E+01
0.10000E+00	0.524652E-01	0.183158E+00	-0.269247E+01	-0.181474E+01
0.12500E+00	0.562027E-01	0.126273E+00	-0.185832E+01	-0.131739E+01
0.15000E+00	0.587788E-01	0.863919E-01	-0.133217E+01	-0.627081E+00
0.20000E+00	0.614332E-01	0.373779E-01	-0.628395E+00	-0.322435E+00
0.25000E+00	0.625166E-01	0.136049E-01	-0.322524E+00	-0.238601E+00
0.30000E+00	0.627937E-01	-0.423403E-03	-0.238601E+00	-0.234540E+00
0.35000E+00	0.624743E-01	-0.122531E-01	-0.234593E+00	-0.248573E+00
0.40000E+00	0.615684E-01	-0.243379E-01	-0.248794E+00	-0.260971E+00
0.45000E+00	0.600405E-01	-0.370953E-01	-0.261510E+00	-0.270643E+00
0.50000E+00	0.578588E-01	-0.504251E-01	-0.271676E+00	-0.290649E+00
0.55000E+00	0.549980E-01	-0.645287E-01	-0.292467E+00	-0.318299E+00
0.60000E+00	0.514060E-01	-0.798740E-01	-0.321349E+00	-0.351217E+00
0.65000E+00	0.470106E-01	-0.968118E-01	-0.356166E+00	-0.387424E+00
0.70000E+00	0.417248E-01	-0.115596E+00	-0.395215E+00	-0.364914E+00
0.75000E+00	0.354509E-01	-0.134850E+00	-0.374913E+00	-0.220448E+00
0.80000E+00	0.282398E-01	-0.149920E+00	-0.227922E+00	-0.333127E-01
0.85000E+00	0.204589E-01	-0.156482E+00	-0.345437E-01	0.436360E+00
0.90000E+00	0.125916E-01	-0.146086E+00	0.450403E+00	0.887695E+00
0.92500E+00	0.908021E-02	-0.129081E+00	0.909973E+00	0.129303E+01
0.95000E+00	0.613755E-02	-0.101294E+00	0.131298E+01	0.169696E+01
0.97500E+00	0.401550E-02	-0.635412E-01	0.170725E+01	0.197152E+01
0.99000E+00	0.325445E-02	-0.359218E-01	0.197534E+01	0.000000E+00
0.10000E+01	0.299400E-02	-0.260451E-01	0.000000E+00	

# PROFILE User's Guide (Appendix D, Sample 5)

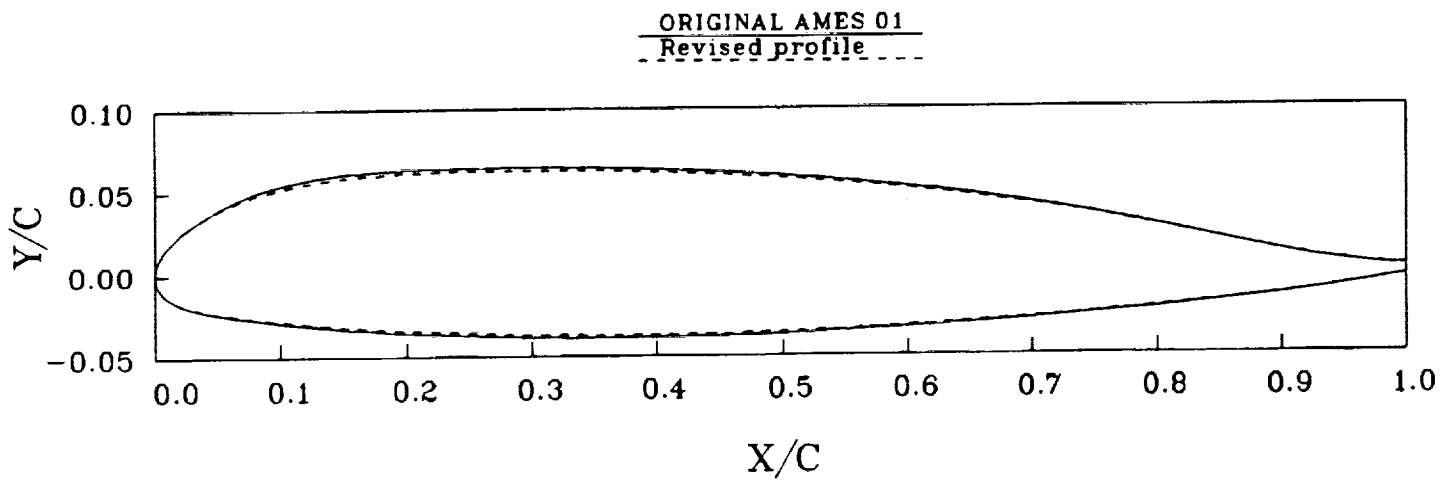
Program PROFILE: REFINE mode used on Ames-01 Rotor Section

Revised lower surface

X	Y	Y'	Y''	CURVATURE
0.000000E+00	0.000000E+00	-0.111396E+02	0.000000E+00	0.000000E+00
0.200000E-03	-0.222792E-02	-0.820962E+01	0.293000E+05	0.517968E+02
0.500000E-03	-0.337231E-02	-0.338862E+01	0.284001E+04	0.643953E+02
0.100000E-02	-0.471162E-02	-0.238112E+01	0.119000E+04	0.690851E+02
0.200000E-02	-0.649774E-02	-0.158212E+01	0.408001E+03	0.622274E+02
0.350000E-02	-0.841192E-02	-0.113812E+01	0.184001E+03	0.529121E+02
0.500000E-02	-0.991210E-02	-0.913869E+00	0.115001E+03	0.462583E+02
0.650000E-02	-0.111535E-01	-0.768594E+00	0.787000E+02	0.392262E+02
0.800000E-02	-0.122179E-01	-0.668895E+00	0.568990E+02	0.327655E+02
0.100000E-01	-0.134379E-01	-0.569194E+00	0.408010E+02	0.267823E+02
0.125000E-01	-0.147334E-01	-0.481192E+00	0.296007E+02	0.216584E+02
0.160000E-01	-0.162362E-01	-0.392639E+00	0.210015E+02	0.169374E+02
0.200000E-01	-0.176388E-01	-0.321032E+00	0.148019E+02	0.127767E+02
0.250000E-01	-0.190589E-01	-0.258519E+00	0.102031E+02	0.925948E+01
0.350000E-01	-0.211339E-01	-0.182703E+00	0.496019E+01	0.472180E+01
0.500000E-01	-0.233165E-01	-0.130291E+00	0.202810E+01	0.197753E+01
0.650000E-01	-0.250427E-01	-0.107819E+00	0.968239E+00	0.951598E+00
0.800000E-01	-0.265510E-01	-0.954425E-01	0.681939E+00	0.672726E+00
0.100000E+00	-0.283235E-01	-0.828729E-01	0.575030E+00	0.569156E+00
0.125000E+00	-0.302156E-01	-0.699720E-01	0.457052E+00	0.453716E+00
0.150000E+00	-0.318221E-01	-0.597200E-01	0.363104E+00	0.361170E+00
0.200000E+00	-0.343542E-01	-0.427184E-01	0.316961E+00	0.316095E+00
0.250000E+00	-0.360939E-01	-0.276242E-01	0.286809E+00	0.286481E+00
0.300000E+00	-0.371166E-01	-0.143183E-01	0.245427E+00	0.245351E+00
0.350000E+00	-0.375258E-01	-0.289231E-02	0.211614E+00	0.211612E+00
0.400000E+00	-0.374059E-01	0.715038E-02	0.190094E+00	0.190080E+00
0.450000E+00	-0.368107E-01	0.165679E-01	0.186609E+00	0.186532E+00
0.500000E+00	-0.357491E-01	0.258600E-01	0.185078E+00	0.184892E+00
0.550000E+00	-0.342247E-01	0.345404E-01	0.162139E+00	0.161849E+00
0.600000E+00	-0.322950E-01	0.421532E-01	0.142368E+00	0.141989E+00
0.650000E+00	-0.300094E-01	0.487119E-01	0.119985E+00	0.119559E+00
0.700000E+00	-0.274238E-01	0.545872E-01	0.115026E+00	0.114514E+00
0.750000E+00	-0.245507E-01	0.608658E-01	0.136117E+00	0.135364E+00
0.800000E+00	-0.213373E-01	0.680970E-01	0.153133E+00	0.152074E+00
0.850000E+00	-0.177410E-01	0.770603E-01	0.205399E+00	0.203583E+00
0.900000E+00	-0.136312E-01	0.897986E-01	0.304133E+00	0.300491E+00
0.925000E+00	-0.112912E-01	0.977784E-01	0.334250E+00	0.329513E+00
0.950000E+00	-0.874231E-02	0.106463E+00	0.360508E+00	0.354465E+00
0.975000E+00	-0.596808E-02	0.114892E+00	0.313831E+00	0.307718E+00
0.990000E+00	-0.420939E-02	0.119222E+00	0.263480E+00	0.257960E+00
0.100000E+01	-0.300400E-02	0.120539E+00	0.000000E+00	0.000000E+00

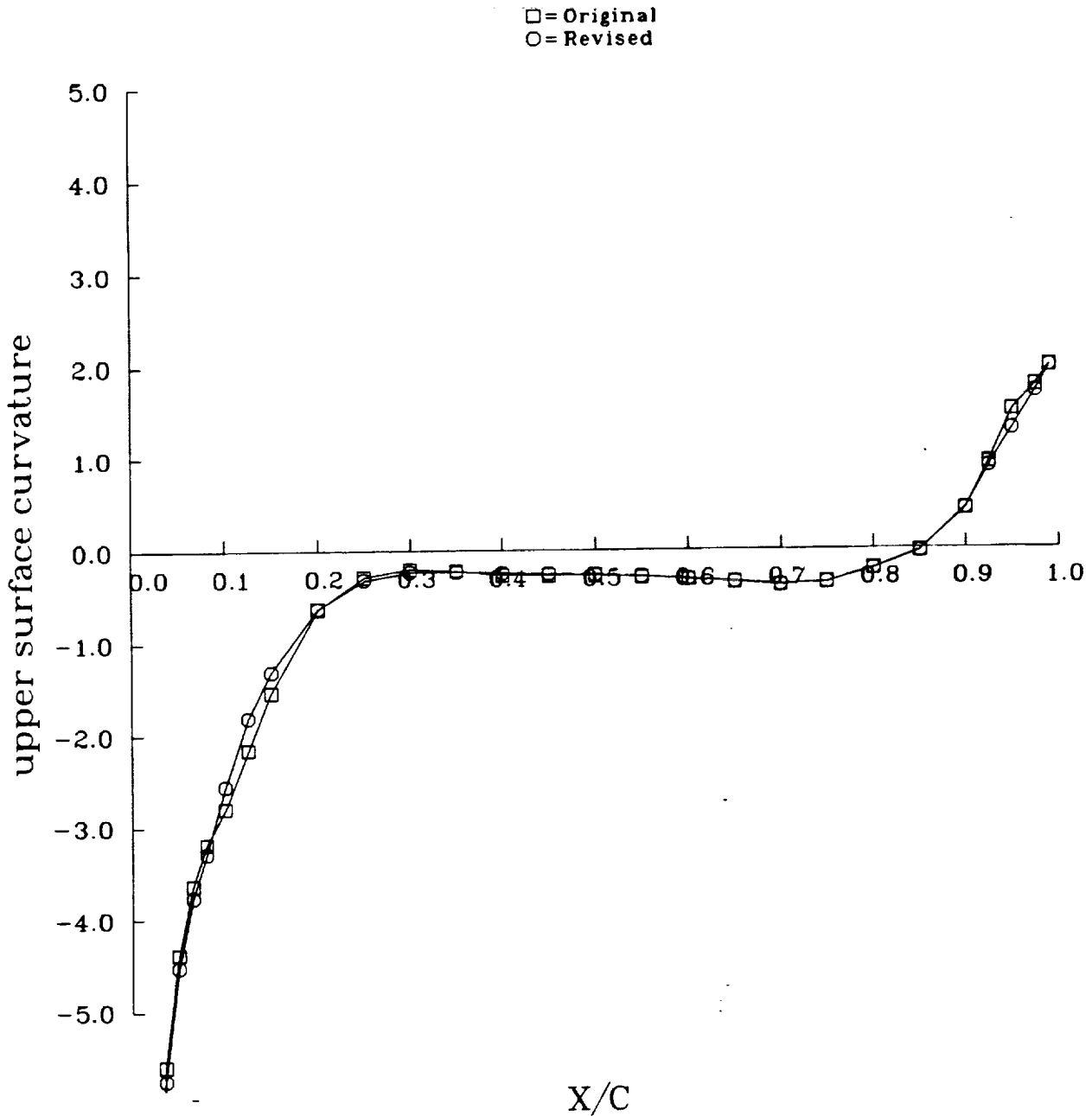
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Program PROFILE: REFINE mode used on Ames-01 Rotor Section  
Curvature smoothed via target  $y''$  distribution; new T/C=10%

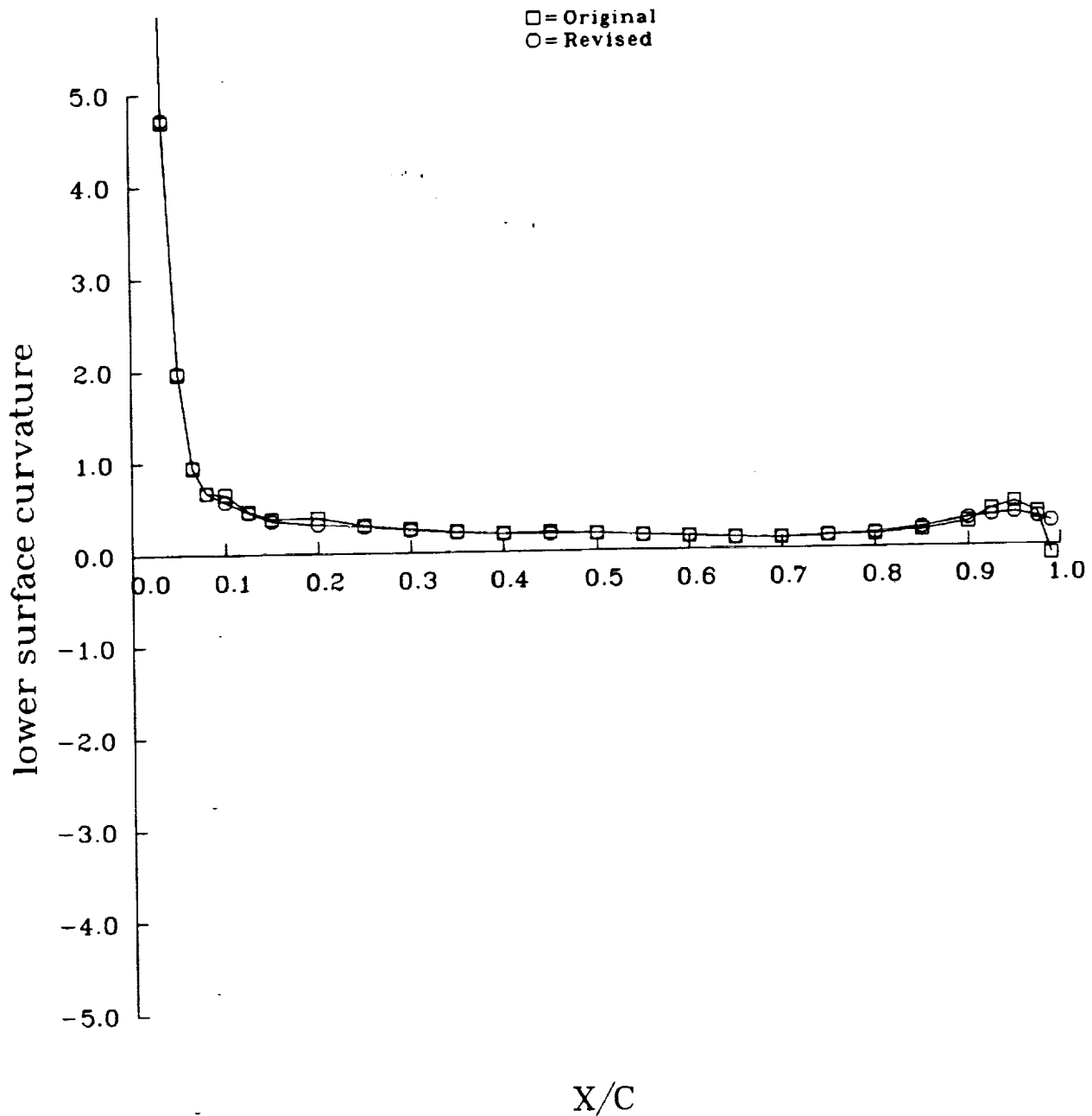




Program PROFILE: REFINE mode used on Ames-01 Rotor Section  
Curvature smoothed via target  $y''$  distribution; new T/C=10%



Program PROFILE: REFINE mode used on Ames-01 Rotor Section  
Curvature smoothed via target  $y''$  distribution; new T/C=10%



(6) Ames-01 Airfoil - Mode 6 (optimize curvature)

The example of the OPTIMIZE option starts with the result from the previous example - a REFINED Ames-01 rotor section. This may not be very representative in that the result achieved here, on something very like it, could have been achieved more efficiently using REFIN instead. As indicated in the body of the text, OPTIMIZE is an experimental scheme at the time of writing. It has worked well on problems constructed with known solution. The present example is more realistic in that the true minimum is not known.

Limited experimentation with different scalings suggests the minimum is poorly defined in this example, and that some solutions found by QMDF (possibly unconverged in the minimization sense) are not acceptable judging by the waviness of the curvature plots. Keep in mind that the choice of 10 Wagner functions is quite arbitrary, as is the target curvature distribution, which is an edited form of the .CRV file output from the previous REFIN example. Note also that this smoothed version of Ames-01 was used as the starting guess rather than the original Ames-01 because successful application of smooth shape functions essentially demands a smooth base profile if the result is also to be smooth.

Since only one surface may be OPTIMIZED at a time, the lower surface (left intact) is suppressed from the outputs shown. About 60 seconds of VAX-11/780 CPU time were used for the complete run in OPTIMIZE mode that follows.

---

Sample Terminal Session - Optimize curvature

---

Welcome to program PROFILE (Applied Aerodynamics Branch, NASA Ames)

PROFILE operating modes:  
 0 = default (no modifications) - just plot and tabulate  
 1 = rectify leading edge definition  
 2 = normalize or de-normalize geometry  
 3 = redistribute the abscissas  
 4 = modify - apply shape functions  
 5 = refine thickness/curvature  
 6 = optimize one surface (bumps + target curvatures)  
 Enter MODE, else <CR> for MODE = 0: 6  
 Enter the PROFILE control file (default is PROFILE.INP):  
 AMES01.INP  
 Enter the airfoil geometry data file (default is AIRFOIL.DAT):

# PROFILE User's Guide (Appendix D, Sample 6)

```

SAMPLE5.DAT
Enter identifier for output files (1 - 9 chars.) else <CR> gives PROFILE.*:
SAMPLE6
Enter plot title (up to 80 chars.) <CR> uses PROFILE for the title:
Program PROFILE: OPTIMIZE mode on REFINED Ames-01 Section
Enter plot subtitle (up to 80 characters) or <CR> if none:
Target curvature distribution; no constraint on thickness
Enter U(pper) or L(ower) to indicate the surface being optimized: U
Original thickness: 10.00000
Enter desired % thickness (<CR> means keep same or don't care): <CR>
Enter thickness penalty parameter (<CR> means no constraint): <CR>
Enter N to use Wagner functions 1:N, or <CR> to use an input file: 10
Enter seed for scale factors. <CR> gives 1000. <CR>
Enter target curvature distribution file name: AMES1TARG.CRV
Do you want full optimization printout? (Y/N; <CR>=No): <CR>
Initial function value: 2.956724
Final function value: 0.1571151
Modified % thickness: 10.38687 Corresponding X: 0.30000000

Modified airfoil: SAMPLE6.DAT
Airfoil plot file: SAMPLE6.PLT
Tabulated results: SAMPLE6.TAB
Curvature OPLOT file: SAMPLE6.CRV
2nd derivatives file: SAMPLE6.YPP

```

SAMPLE6.TAB file

Program PROFILE (Applied Aerodynamics Branch, NASA Ames)

Operating mode: 6  
Control file : AMES01.INP  
Geometry file : SAMPLES.DAT  
Output file id: SAMPLE6  
Profiles found: 1

Case: Program PROFILE: OPTIMIZE mode on REFINED Ames-01 Section

Original thickness: 10.00000  
Corresponding x/c: 0.3500000  
Target thickness : 10.00000  
Penalty parameter : 0.0000000E+00

# Shape Function Description

Function 1: Name: WAGNER

Parameter	Value	Scale	Active?
N	1.000000000	1.00000	F
MULTIP	0.000000000	1000.00000	T

Function 2: Name: WAGNER

Parameter	Value	Scale	Active?
N	2.000000000	1.00000	F
MULTIP	0.000000000	1000.00000	T

Function 3: Name: WAGNER

Parameter	Value	Scale	Active?
N	3.000000000	1.00000	F
MULTIP	0.000000000	1000.00000	T

Function 4: Name: WAGNER

PROFILE User's Guide (Appendix D, Sample 6)

Parameter	Value	Scale	Active?
N	4.000000000	1.00000	F
MULTIP	0.000000000	1000.00000	T

Function 5: Name: WAGNER

Parameter	Value	Scale	Active?
N	5.000000000	1.00000	F
MULTIP	0.000000000	1000.00000	T

Function 6: Name: WAGNER

Parameter	Value	Scale	Active?
N	6.000000000	1.00000	F
MULTIP	0.000000000	3000.00000	T

Function 7: Name: WAGNER

Parameter	Value	Scale	Active?
N	7.000000000	1.00000	F
MULTIP	0.000000000	3000.00000	T

Function 8: Name: WAGNER

Parameter	Value	Scale	Active?
N	8.000000000	1.00000	F
MULTIP	0.000000000	3000.00000	T

Function 9: Name: WAGNER

Parameter	Value	Scale	Active?
N	9.000000000	1.00000	F
MULTIP	0.000000000	3000.00000	T

Function 10: Name: WAGNER

Parameter	Value	Scale	Active?
N	10.000000000	1.00000	F
MULTIP	0.000000000	3000.00000	T

PROFILE User's Guide (Appendix D, Sample 6)

N	10.00000000	1.00000	F
MULTIP	0.00000000	3000.00000	T

Total number of active parameters: 10

Target curvature distribution found:

Target curvature for smoothing Anes-01 via OPTIMIZE option

36 Upper surface

0.002000	-4.20E+01
0.003500	-3.55E+01
0.005000	-3.01E+01
0.006500	-2.42E+01
0.008000	-1.97E+01
0.010000	-1.60E+01
0.012500	-1.31E+01
0.016000	-1.08E+01
0.020000	-9.075484
0.025000	-7.347380
0.035000	-5.611382
0.050000	-4.386197
0.065000	-3.636765
0.080000	-3.100000
0.100000	-2.500000
0.125000	-1.850000
0.150000	-1.300000
0.200000	-0.750000
0.250000	-0.500000
0.300000	-0.400000
0.350000	-0.300000
0.400000	-0.270000
0.450000	-0.270000
0.500000	-0.280000
0.550000	-0.290000
0.600000	-0.310000
0.650000	-0.340000
0.700000	-0.380000
0.750000	-0.360000
0.800000	-0.250000
0.850000	0.000000
0.900000	0.430000
0.925000	0.930000
0.950000	1.500000
0.975000	1.850000
0.990000	1.970000

Initial function value: 2.956724

CENDIF: Begin gradient calculation.



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I	DVAR	Gradient	Diag of Hessian	Old H	New H	No Fun	ERROR
1	0.000000000000E+00	-.121401095390E+01	0.555637001991E+00	-.1000000004750E-02	0.599956000224E-02	2	0
2	0.000000000000E+00	-.144863176346E+01	0.598946452141E+00	-.1000000004750E-02	0.577857811004E-02	4	0
3	0.000000000000E+00	-.192654252052E+01	0.181501805782E+01	-.1000000004750E-02	0.331951421686E-02	2	0
4	0.000000000000E+00	-.199921035767E+01	0.228622460365E+01	-.1000000004750E-02	0.295770959929E-02	2	0
5	0.000000000000E+00	-.179590487480E+01	0.466772842407E+01	-.1000000004750E-02	0.206996104680E-02	2	0
6	0.000000000000E+00	-.321567624807E+00	0.656104505062E+00	-.1000000004750E-02	0.552113633603E-02	2	0
7	0.000000000000E+00	0.193203654289E-01	0.140268611908E+01	-.1000000004750E-02	0.377602386288E-02	4	4
8	0.000000000000E+00	0.551941275597E+00	0.313713216782E+01	-.1000000004750E-02	0.252492562688E-02	2	0
9	0.000000000000E+00	0.124799859524E+01	0.371022129059E+01	-.1000000004750E-02	0.232174806297E-02	2	0
10	0.000000000000E+00	0.188582098484E+01	0.357249140739E+01	-.1000000004750E-02	0.236607971601E-02	2	0

FINAL ITERATION	23	FUNCTION VALUE	0.157115057110786E+00
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## NUMBER OF FUNCTION EVALUATIONS

ELEMENTS OF DIAGONAL MATRIX				
0.64749810791056E+03	0.258233761787415E+01	0.345959401130676E+01	0.110084180831909E+02	0.110124807357788E+02
0.265563583374023E+01	0.240346479415894E+01	0.473223161697388E+01	0.120080318450928E+02	0.283985352516174E+01

0.455008357763290E+00	0.718071579933167E+00	-0.348991692066193E+00	-0.354999959468842E+00	0.261269658803940E+00
0.465233862400055E+00	0.607828080654144E+00	-0.688366293907166E+00	-0.168203935027122E+00	0.483570605516434E+00
0.210406136512756E+01	-0.420159041881561E+00	-0.353238672018051E+00	0.758746564388275E-01	
0.219186973571777E+01	-0.211977869272232E+00	-0.110824108123779E+00		
0.59577387571348E+00	0.608660042285919E+00			
0.162172114849091E+01				
-0.272022634744644E+00	-0.232148736715317E+00	0.580232620239258E+00	0.165469601750374E+00	-0.137303292751312E+01
0.229113149642944E+01				

# PROFILE User's Guide (Appendix D, Sample 6)

0.441707491874695E+00	-0.565621316432953E+00	0.826746881008148E+00	-0.682034790515900E-01	-0.999207317829132E+00
-0.351663064956665E+01	-0.481479614973068E+00	0.980903506278992E+00	0.100726418197155E+00	-0.916221857070923E+00
-0.155222669243813E+00	-0.410429060459137E+00	0.768238723278046E+00	0.612887255847454E-01	
-0.111668741703033E+01	0.731270313262939E+00	0.941448450088501E+00		
0.126993811130524E+01	0.717702090740204E+00			

LOWER BOUND ON CONDITION NUMBER OF HESSIAN 0.269401947021484E+03

NORM OF GRADIENT 0.760568976402283E-01

Repeat of best function evaluation: 0.1571151

# PROFILE User's Guide (Appendix D, Sample 6)

## Shape Function Description

Function 1: Name: WAGNER			
Parameter	Value	Scale	Active?
N	1.00000000	1.00000	F
MULTIP	0.00355092	1000.00000	T
Function 2: Name: WAGNER			
Parameter	Value	Scale	Active?
N	2.00000000	1.00000	F
MULTIP	0.00345195	1000.00000	T
Function 3: Name: WAGNER			
Parameter	Value	Scale	Active?
N	3.00000000	1.00000	F
MULTIP	0.00119199	1000.00000	T
Function 4: Name: WAGNER			
Parameter	Value	Scale	Active?
N	4.00000000	1.00000	F
MULTIP	-0.00134125	1000.00000	T
Function 5: Name: WAGNER			
Parameter	Value	Scale	Active?
N	5.00000000	1.00000	F
MULTIP	-0.00145982	1000.00000	T
Function 6: Name: WAGNER			
Parameter	Value	Scale	Active?
N	6.00000000	1.00000	F

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MULTIP -0.00078383 3000.00000 T

Function 7: Name: WAGNER

Parameter	Value	Scale	Active?
N	7.00000000	1.00000	F
MULTIP	0.00024925	3000.00000	T

Function 8: Name: WAGNER

Parameter	Value	Scale	Active?
N	8.00000000	1.00000	F
MULTIP	0.00038820	3000.00000	T

Function 9: Name: WAGNER

Parameter	Value	Scale	Active?
N	9.00000000	1.00000	F
MULTIP	-0.00017500	3000.00000	T

Function 10: Name: WAGNER

Parameter	Value	Scale	Active?
N	10.00000000	1.00000	F
MULTIP	-0.00002218	3000.00000	T

Total number of active parameters: 10

Modified % thickness: 10.38687  
Corresponding abscissa: 0.3000000

# PROFILE User's Guide (Appendix D, Sample 6)

Program PROFILE: REFINE mode used on Ames-01 Rotor Section

Original upper surface

X	Y	Y'	Y''	CURVATURE
0.00000E+00	0.00000E+00	0.118750E+02	0.00000E+00	0.00000E+00
0.20000E-03	0.237500E-02	0.897433E+01	-0.290067E+05	-0.393960E+02
0.50000E-03	0.376200E-02	0.411583E+01	-0.338333E+04	-0.445254E+02
0.10000E-02	0.539700E-02	0.292200E+01	-0.139200E+04	-0.472550E+02
0.20000E-02	0.762300E-02	0.198973E+01	-0.472534E+03	-0.427894E+02
0.35000E-02	0.100760E-01	0.148000E+01	-0.207111E+03	-0.363442E+02
0.50000E-02	0.120630E-01	0.123267E+01	-0.122667E+03	-0.306737E+02
0.65000E-02	0.137740E-01	0.108100E+01	-0.795558E+02	-0.249124E+02
0.80000E-02	0.153060E-01	0.980047E+00	-0.550475E+02	-0.200535E+02
0.10000E-01	0.171560E-01	0.885800E+00	-0.392000E+02	-0.164422E+02
0.12500E-01	0.192480E-01	0.801705E+00	-0.280762E+02	-0.133349E+02
0.16000E-01	0.218820E-01	0.716605E+00	-0.205523E+02	-0.110377E+02
0.20000E-01	0.245840E-01	0.644256E+00	-0.156223E+02	-0.928068E+01
0.25000E-01	0.276100E-01	0.576400E+00	-0.115200E+02	-0.749167E+01
0.35000E-01	0.327980E-01	0.479493E+00	-0.786134E+01	-0.576348E+01
0.50000E-01	0.391060E-01	0.379033E+00	-0.553335E+01	-0.452417E+01
0.65000E-01	0.441690E-01	0.305267E+00	-0.430223E+01	-0.376401E+01
0.80000E-01	0.482640E-01	0.246021E+00	-0.359714E+01	-0.329364E+01
0.10000E+00	0.524650E-01	0.183148E+00	-0.269021E+01	-0.256031E+01
0.12500E+00	0.562030E-01	0.126280E+00	-0.185919E+01	-0.181559E+01
0.15000E+00	0.587790E-01	0.863865E-01	-0.133227E+01	-0.131749E+01
0.20000E+00	0.614330E-01	0.373800E-01	-0.627997E+00	-0.626683E+00
0.25000E+00	0.625170E-01	0.136101E-01	-0.322802E+00	-0.322712E+00
0.30000E+00	0.627940E-01	-0.430096E-03	-0.238799E+00	-0.238799E+00
0.35000E+00	0.624740E-01	-0.122599E-01	-0.234403E+00	-0.234350E+00
0.40000E+00	0.615680E-01	-0.243401E-01	-0.248797E+00	-0.248576E+00
0.45000E+00	0.600400E-01	-0.370899E-01	-0.261201E+00	-0.260663E+00
0.50000E+00	0.578590E-01	-0.504200E-01	-0.272002E+00	-0.270968E+00
0.55000E+00	0.549980E-01	-0.645300E-01	-0.292398E+00	-0.290581E+00
0.60000E+00	0.514060E-01	-0.798701E-01	-0.321200E+00	-0.318151E+00
0.65000E+00	0.470110E-01	-0.968100E-01	-0.356399E+00	-0.351447E+00
0.70000E+00	0.417250E-01	-0.115600E+00	-0.395197E+00	-0.387406E+00
0.75000E+00	0.354510E-01	-0.134850E+00	-0.374800E+00	-0.364804E+00
0.80000E+00	0.282400E-01	-0.149920E+00	-0.228001E+00	-0.220524E+00
0.85000E+00	0.204590E-01	-0.156480E+00	-0.344031E-01	-0.331771E-01
0.90000E+00	0.125920E-01	-0.146100E+00	0.449609E+00	0.435589E+00
0.92500E+00	0.908000E-02	-0.129080E+00	0.911987E+00	0.889660E+00
0.95000E+00	0.613800E-02	-0.101280E+00	0.131201E+01	0.129208E+01
0.97500E+00	0.401600E-02	-0.635800E-01	0.170399E+01	0.169371E+01
0.99000E+00	0.325400E-02	-0.359200E-01	0.198400E+01	0.198017E+01
0.10000E+01	0.299400E-02	-0.260000E-01	0.000000E+00	0.000000E+00

# PROFILE User's Guide (Appendix D, Sample 6)

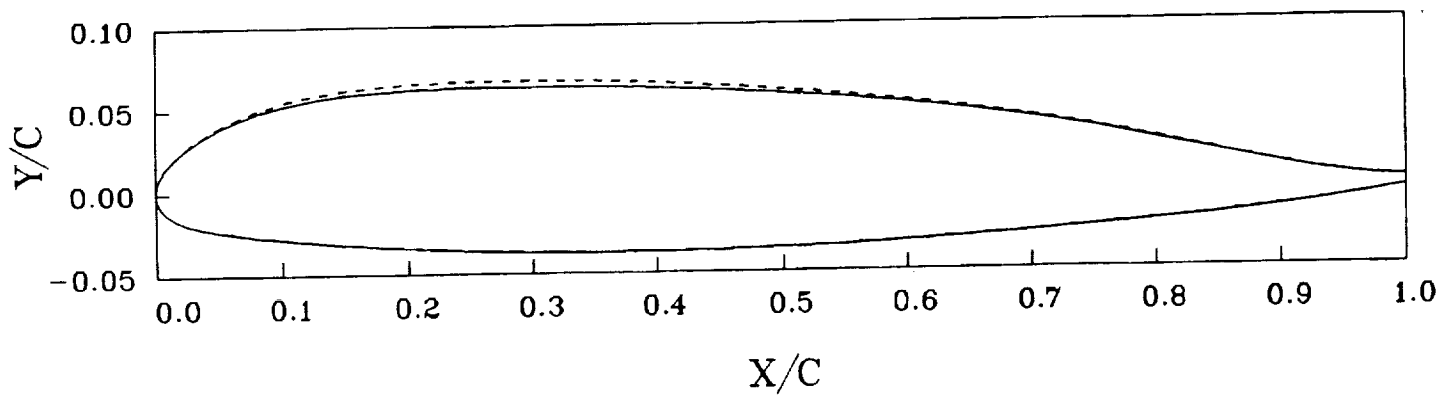
PROFILE: OPTIMIZE mode on REFINED Ames-01 Section

Revised upper surface

X	Y	Y'	Y''	CURVATURE
0.00000E+00	0.00000E+00	0.120184E+02	0.00000E+00	0.00000E+00
0.20000E-03	0.240368E-02	0.908238E+01	-0.293602E+05	-0.384866E+02
0.50000E-03	0.380718E-02	0.416434E+01	-0.342672E+04	-0.436232E+02
0.100000E-02	0.546102E-02	0.295634E+01	-0.140531E+04	-0.462314E+02
0.200000E-02	0.771470E-02	0.201513E+01	-0.477108E+03	-0.419076E+02
0.350000E-02	0.102007E-01	0.150064E+01	-0.208885E+03	-0.356204E+02
0.500000E-02	0.122166E-01	0.125138E+01	-0.123465E+03	-0.300382E+02
0.500000E-02	0.139548E-01	0.109881E+01	-0.799584E+02	-0.243808E+02
0.800000E-02	0.155130E-01	0.997405E+00	-0.552446E+02	-0.196081E+02
0.100000E-01	0.173974E-01	0.902890E+00	-0.392701E+02	-0.160573E+02
0.125000E-01	0.195319E-01	0.818719E+00	-0.280667E+02	-0.130017E+02
0.200000E-01	0.222255E-01	0.733726E+00	-0.205005E+02	-0.107443E+02
0.250000E-01	0.249964E-01	0.661619E+00	-0.155533E+02	-0.902201E+01
0.350000E-01	0.281101E-01	0.594109E+00	-0.114506E+02	-0.727612E+01
0.500000E-01	0.334786E-01	0.497822E+00	-0.780684E+01	-0.560072E+01
0.500000E-01	0.400677E-01	0.398015E+00	-0.550075E+01	-0.441190E+01
0.650000E-01	0.454191E-01	0.324576E+00	-0.429105E+01	-0.369245E+01
0.800000E-01	0.498050E-01	0.265346E+00	-0.360635E+01	-0.325644E+01
0.100000E+00	0.543906E-01	0.202068E+00	-0.272147E+01	-0.256291E+01
0.125000E+00	0.585918E-01	0.144114E+00	-0.191487E+01	-0.185672E+01
0.150000E+00	0.615963E-01	0.102426E+00	-0.142013E+01	-0.139807E+01
0.200000E+00	0.649425E-01	0.482459E-01	-0.747098E+00	-0.744497E+00
0.250000E+00	0.664209E-01	0.180927E-01	-0.459034E+00	-0.458809E+00
0.300000E+00	0.667517E-01	-0.249693E-02	-0.364544E+00	-0.364541E+00
0.350000E+00	0.661712E-01	-0.197448E-01	-0.325378E+00	-0.325188E+00
0.400000E+00	0.647772E-01	-0.351566E-01	-0.291089E+00	-0.290550E+00
0.450000E+00	0.626555E-01	-0.487938E-01	-0.254404E+00	-0.253498E+00
0.500000E+00	0.598978E-01	-0.608677E-01	-0.228548E+00	-0.227284E+00
0.550000E+00	0.565688E-01	-0.724147E-01	-0.233333E+00	-0.231510E+00
0.600000E+00	0.526564E-01	-0.849930E-01	-0.269799E+00	-0.266902E+00
0.650000E+00	0.480695E-01	-0.100012E+00	-0.330970E+00	-0.326066E+00
0.700000E+00	0.426552E-01	-0.118347E+00	-0.402432E+00	-0.394123E+00
0.750000E+00	0.362348E-01	-0.138546E+00	-0.405510E+00	-0.394108E+00
0.800000E+00	0.288006E-01	-0.155109E+00	-0.257005E+00	-0.248001E+00
0.850000E+00	0.207239E-01	-0.162212E+00	-0.271322E-01	-0.260955E-01
0.900000E+00	0.125794E-01	-0.150188E+00	0.508084E+00	0.491365E+00
0.950000E+00	0.898345E-02	-0.131204E+00	0.101069E+01	0.985141E+00
0.950000E+00	0.601921E-02	-0.100860E+00	0.141682E+01	0.139547E+01
0.975000E+00	0.394047E-02	-0.610728E-01	0.176613E+01	0.175630E+01
0.990000E+00	0.322307E-02	-0.328747E-01	0.199361E+01	0.199038E+01
0.100000E+01	0.299400E-02	-0.229067E-01	0.000000E+00	0.000000E+00

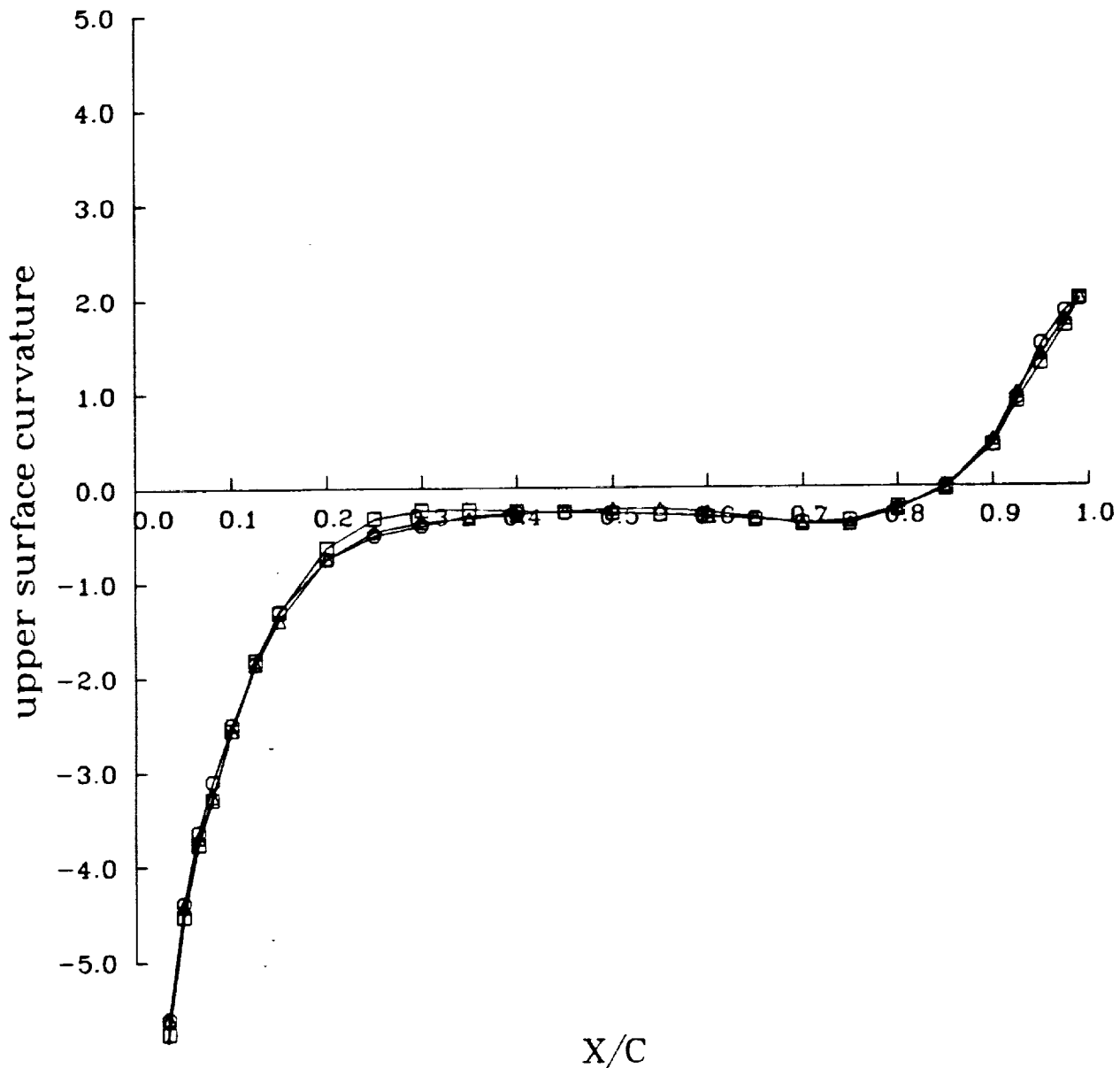
Program PROFILE: OPTIMIZE mode on REFINEd Ames-01 Section  
Target curvature distribution; no constraint on thickness

Program PROFILE: REFINE mode used on Ames-01 Rotor Section  
Revised profile



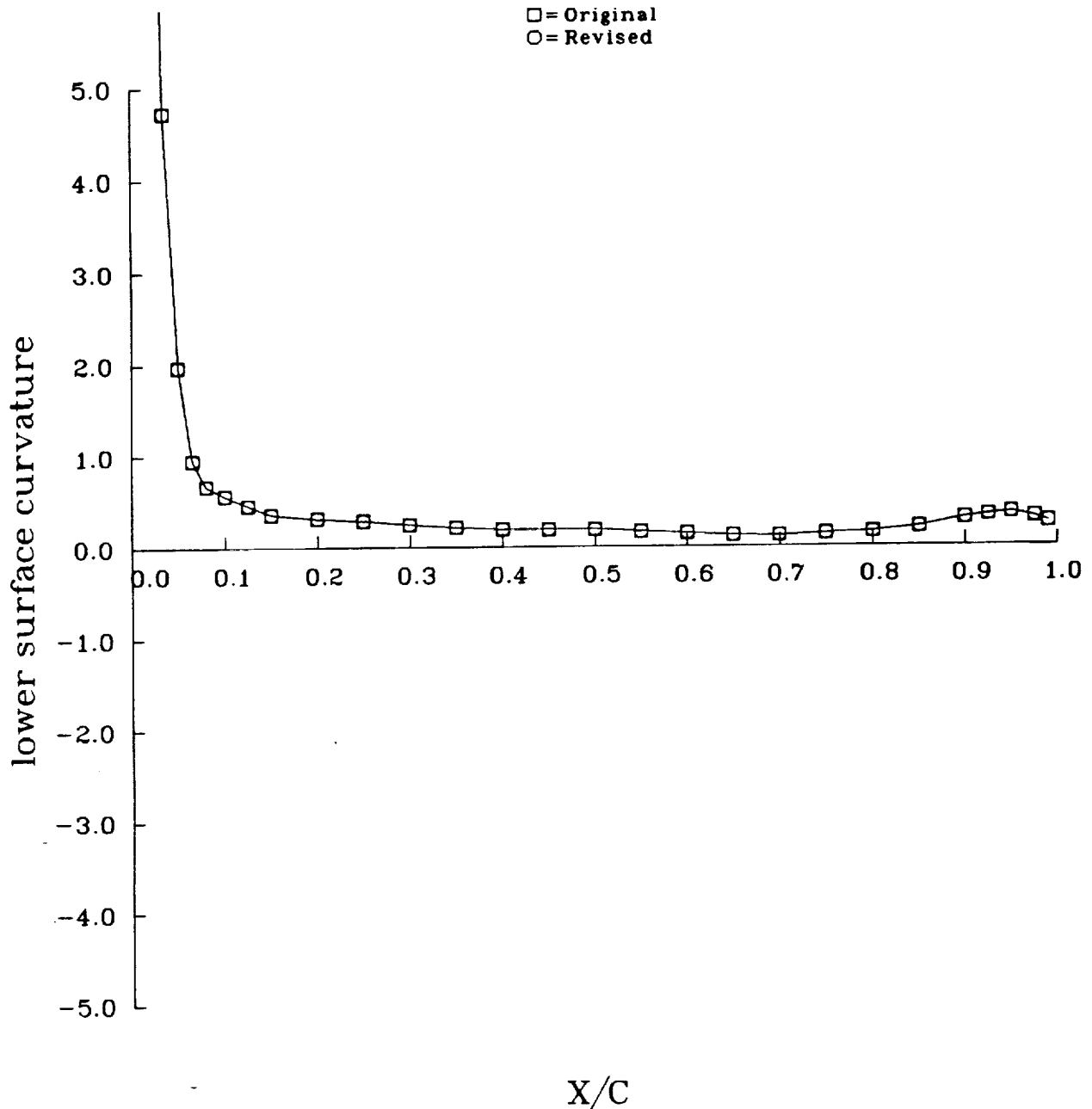
Program PROFILE: OPTIMIZE mode on REFINed Ames-01 Section  
Target curvature distribution; no constraint on thickness

□ = Original  
○ = Target  
△ = Revised





Program PROFILE: OPTIMIZE mode on REFINEd Ames-01 Section  
Target curvature distribution; no constraint on thickness



X/C



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16. Abstract <p>This report provides user information for program PROFILE, an aerodynamics design utility for refining, plotting, and tabulating airfoil profiles. The theory and implementation details for two of the more complex options are also presented. These are the REFINES option, for smoothing curvature in selected regions while retaining or seeking some specified thickness ratio, and the OPTIMIZE option, which seeks a specified curvature distribution. REFINES uses linear techniques to manipulate ordinates via the central difference approximation to second derivatives, while OPTIMIZE works directly with curvature using nonlinear least squares techniques.</p> <p>Use of programs QPLOT and BPLLOT is also described, since all of the plots provided by PROFILE (airfoil coordinates, curvature distributions) are achieved via the general-purpose QPLOT utility. BPLLOT illustrates (again, via QPLOT) the shape functions used by two of PROFILE's options. These three utilities should be distributed as one package. They were designed and implemented for the Applied Aerodynamics Branch at NASA Ames Research Center, Moffett Field, California. They are all written in FORTRAN and run on a VAX-11/780 under VMS.</p>			
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